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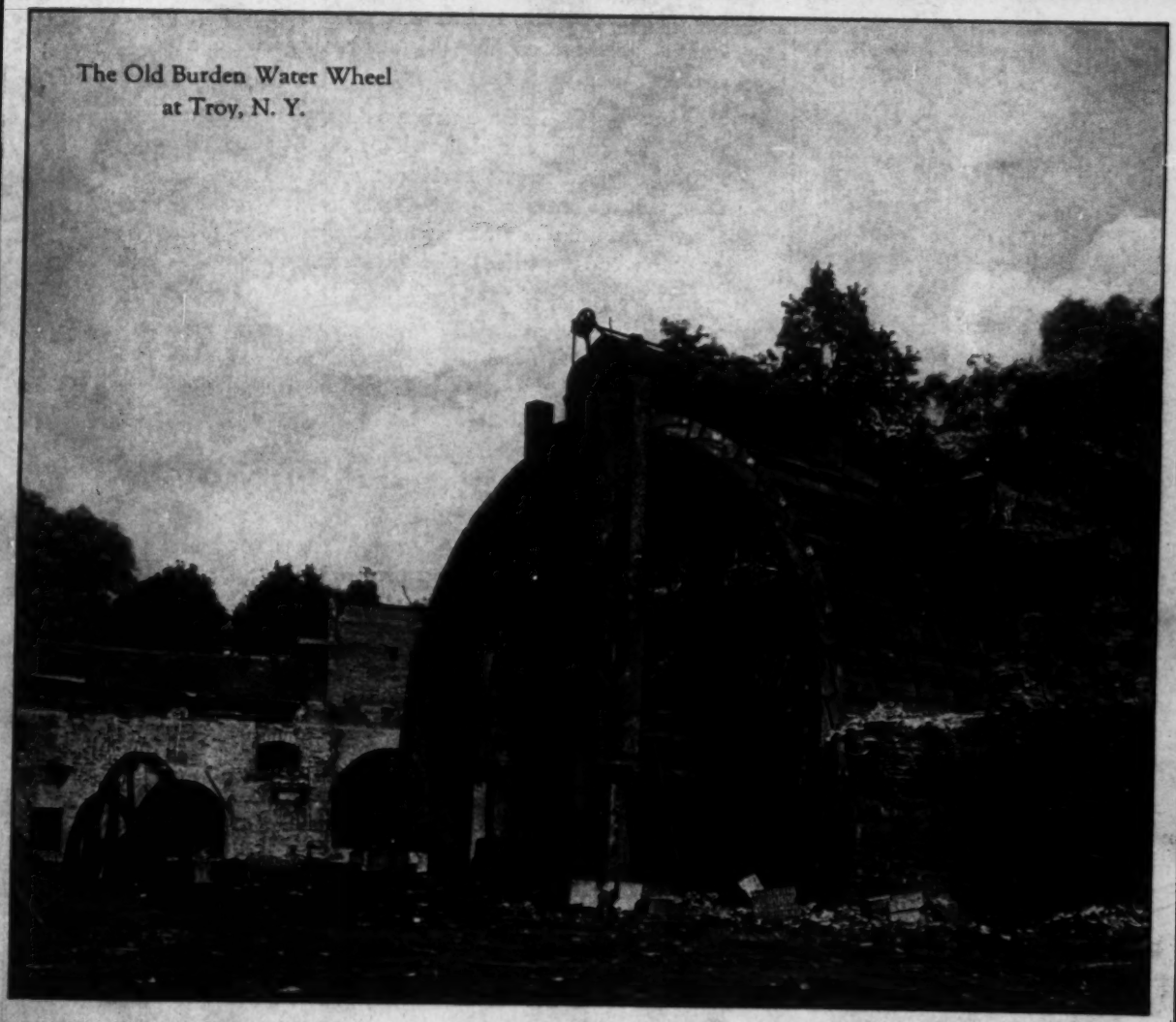

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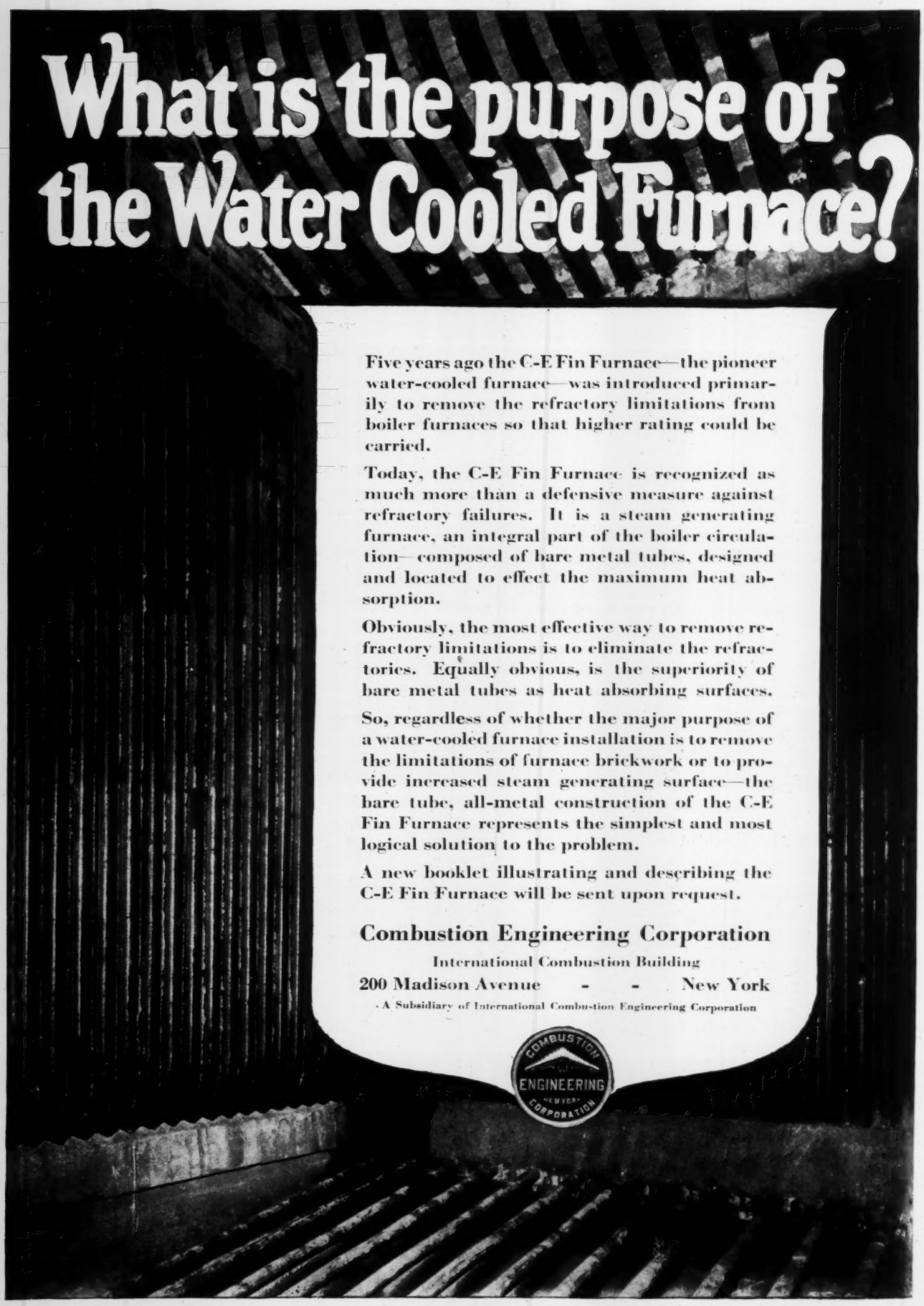
at Troy, N. Y.

February 1928

What is the purpose of the Water Cooled Furnace?



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Contributors to This Issue

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Dr. Adams is president of the American Economic Association and a past-president of the National Tax Association. He has served as tax commissioner in the state of Wisconsin, and as chairman of the Excess Profits Tax Advisers, U. S. Treasury Department. He has also been chairman of the Advisory Tax Board of the U. S. Treasury Department and economic adviser to that department. This year he was appointed Government representative to the Conference of Technical Experts on Double Taxation and Tax Evasion, League of Nations. He is a member of the Advisory Tax Committee of the Joint Congressional Committee on International Revenue Taxation.

* * * * *

W. E. Wickenden, director of investigation for the Society for the Promotion of Engineering Education, received the degree of B.S. from Denison University and then for several years served as instructor in the University of Wisconsin. From 1909 to 1914 Mr. Wickenden was associated with Massachusetts Institute of Technology as assistant professor of electrical engineering, resigning to become personnel manager of the Western Electric Co. He served for two years as assistant vice-president with the American Telephone & Telegraph Co. before accepting his present position in 1923.

H. V. Coes, president and general manager of the Belden Manufacturing Co., Chicago, was graduated from Massachusetts Institute of Technology. He has been associated with the Searchlight Gas Co., Lockwood, Greene & Co., and Ford, Bacon & Davis. Mr. Coes assisted in the design, and built and operated the largest carbonic-acid plant in the world at Cambridge, Mass. He has reorganized munitions plants in Canada and the United States. He was the co-inventor with C. A. Howard of a locomotive automatic stop and with G. I. Rhodes of a pneumatic conveyor for handling hot material without oxidation or re-ignition. He is a frequent contributor to the technical press.

* * * * *

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H. E. Rockefeller

E. L. Robinson

* * * * *

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* * * * *

At the **Steam Table Research** Session of the last Annual Meeting of The American Society of Mechanical Engineers there were presented six reports. Geo. A. Orrok, who reported on general progress, is chairman of the Steam Table Research Fund Executive Committee and is a consulting engineer of New York City. L. B. Smith, who reports on the progress of the work at Massachusetts Institute of Technology, is research assistant at the Research Laboratory of Physical Chemistry at that institution. N. S. Osborne, H. F. Stimson, and E. F. Fiock, who are associated with the United States Bureau of Standards, together report on the progress of the work at the Bureau. Harvey N. Davis, who writes on steam research, holds the chair of mechanical engineering at Harvard University. J. H. Keenan is engaged in development and research for the steam design of the General Electric Company's large steam turbines, and writes on proposed steam-chart calculation. E. L. Robinson, who contributes a report on reheat factors, is also associated with the General Electric Co. in their turbine-engineering department.

MECHANICAL ENGINEERING

Volume 50 February, 1928 No. 2

The Relation Between Industry and Taxation

Third Henry Robinson Towne Lecture on the Relation Between Engineering and Economics

By T. S. ADAMS,[1] NEW HAVEN, CONN.

T. S. ADAMS

I AM TO SPEAK about American industry and taxation: in particular, the attitude which industry should take toward taxation in the next ten or fifteen years. I must discuss this subject from the standpoint of an economist—an economist both sympathetic toward and reasonably familiar with industry, but still as an economist and not an industrialist or business man. When I speak of the attitude which industry *should* take, I mean the attitude which industry should take having due regard both to its own and to the general welfare—at once the prudent attitude and what President Wilson might have called the "handsome attitude." We look to industry for an enlightened selfishness, but American industry has taught us to look for something more than pure selfishness.

The Rising Tide of Public Expenditure and Taxation

The beginning of wisdom in the subject of taxation is an appreciation of the power and diversity—particular the diversity—of the forces which control the shaping of tax laws.

First and most mighty is the mysterious power or appetite of the leviathan we call the state. It will live and carry on, by fair means if possible; if not—nevertheless, the state will live. Almost eleven years ago to a day, in this city, I spoke of this phenomenon in words which I cannot now forbear to quote:

"The continual increase of public expenditures is one of the most irritating, fascinating, and mysterious of social phenomena. It is irritating, because it implies a corresponding increase of taxation. It is fascinating because apparently it cannot be checked. It is mysterious because we do not know in any genuine and fundamental way why it cannot be checked. Regularly, after paying his taxes, the indignant taxpayer insists that 'it must be stopped.' And regularly, before election, aspiring politicians tell him that 'it can be stopped.' But it is not stopped. It characterizes democracies as well as less popular governments; it is particularly marked just after a democratic has succeeded a monarchical form of government. It seems to partake of the resistlessness of an elemental force of nature. Indeed, one of the sanest and most careful economists has formulated the facts as an invariable economic law.

"Public expenditures seem to thrive on opposition—here is the element of mystery. They make their way in the very face of one of the most powerful forces known to history—the unceasing opposition of the taxpayer. His resentment has uprooted dynasties, overthrown administration after administration, and generated innumerable upheavals upon which opposition parties have ridden into power pledged to 'retrenchment and reform.' But the politician who is put into office to reduce taxes is frequently thrown out for increasing them. Occasionally the tide is stemmed in one department of government—as in the English national government after the Crimean War, or in many of our state governments after the Civil War. But the saving accomplished in one department of government is simply sopped up by another branch, and, surveying all divisions of government, the majestic march of costs goes on undisturbed."[2]

The old story has repeated itself once more. The extensive studies of the National Industrial Conference Board[3] indicate that since 1921 state and local taxes have increased more rapidly than federal taxes have declined, and it is highly probable that a similar or greater increase will mark the future. According to the authority cited, state, local, and federal taxes increased from $6,961,000,000 in 1922 to $7,907,000,000 in 1924; the per capita tax from $63.72 in 1922 to $70.99 in 1924; per person gainfully employed, from $168.42 to $182.94; per family, from $276.55 to $304.23; and per $100 of national income, from $10.90 in 1922 to $12.50 in 1924.

Industry to Bear Heavier and Not Lighter Tax Burdens

Cherish no illusions about further reduction of expenditures and taxation. American industry in the future must look forward to heavier and not lighter tax burdens.

The next most powerful force at work expresses itself in the class struggle by which groups that for one reason or another are politically powerful, try to rid themselves of the burden of taxes that will inevitably be collected from somebody. Class politics is of the essence of tax making.

In this connection attention may be called to a significant psychological phenomenon. The first impulse of a healthy human, when threatened with a tax, is to resist. But to resist successfully, the individual must usually work in and with a group; and insensibly the raw egoistic impulse which first animated him is changed to a group impulse which accepts class standards and a group ethic. Individual selfishness loses itself frequently in class selfishness, and in time the latter may change into something higher. The guiding light becomes social or national in its range. The greatest good of the greatest number replaces the "good of me and my class." A sense of general

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[1] Professor of Political Economy, Yale University; President, American Economic Association.

Delivered at the Annual Meeting, New York, December 5 to 8, 1927, of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS.

[2] From an address on "Increase of Public Expenditures and Taxes," delivered at the 10th annual meeting of the Association of Life Insurance Presidents, New York, Dec. 15, 1916.

[3] "Cost of Government in the United States," 1923, chapters II and IV.

equity, of fair play, of broad social policy based upon disinterested analysis, is awakened and plays a powerful part. Ethical and social forces of a disinterested and quasi-scientific character thus assume roles of importance and power in the political arena where taxes are made and unmade. Tax making rises above what the war aviators called a "dog fight."

Taxes are as complex as life. Some politicians would mold taxes wholly in accordance with political expediency, but statesmen know that in the long run this would be impolitic. The socialists would tax only the classes and exempt the masses, but where this policy becomes supreme the classes migrate or melt into the masses. The moralist calls for just taxes; but taxes cannot just be just. The administrator asks for simple taxes; but experience shows that they cannot simply be simple. The business man demands practical taxes; but financial history proves that it is impracticable to make them merely practical. The legalist wants taxes administered strictly according to law; but the records of the income tax and the property tax make it clear that such taxes cannot be successfully administered by methods meticulously legal.

Factors Which Make and Shape Our Tax Laws

I cannot pursue further here the (to me, at least) fascinating analysis of the factors which make and shape our tax laws. They run the gamut from the crassest individual selfishness to the highest patriotic and scientific motives. All these forces are inevitable and, in my philosophy at least, may be salutary. Certainly they throw light upon the proper attitude toward taxation of organized industry.

They show first of all that tax making is a hard game, in which the class that does not work for its own interest loses that interest. Taxes do not merely happen; they are forged in the heat of a class struggle which, although ordinarily conducted within the bounds of decency and law, is none the less a struggle. Taxes emerge—to change the simile—as a resultant of these jarring forces; and no group of men is disinterested or scientific or wise enough to make tax laws for other groups without the active participation of the latter in the making thereof.

Good tax laws cannot be made without the assistance of the skilled administrator, the wise legislator, and the disinterested judge. But these men cannot make good taxes without feeling the pull and haul of the taxpayers themselves. President Coolidge and Secretary Mellon have recently criticized the Chamber of Commerce of the United States for demanding a reduction of $400,000,000 in the present tax budget. In my opinion, both sides in this discussion depend too much upon estimates and statistics. This aspect of the debate will be referred to later. In any event, the debate itself is a wholesome sign. History and political experience put one truth beyond all dispute—the truth that executives cannot be left to determine wholly of and by themselves how much and what kind of taxes are expedient. It is very necessary to right solutions of such questions that taxpayers pull at the coat-tails of distinguished statesmen and say, emphatically and insistently, what they believe they can and ought to pay. Neither the taxpayer nor the executive will be right in the typical and average case. The truth lies between.

What has been said is not mere repetition of the democratic commonplace that there should be no taxation without representation. I am making the equally important point that in taxation—particularly when the question at issue deals with future expenditures and future tax yields—the facts will in material part be what you make them. In this domain of thought the truth emerges only from contest, because the contest in part determines what is the truth. How much money Congress will appropriate and how much revenue the Treasury will collect in the next two years, depend materially upon how hard and by what human forces they are pressed. If I were a business man I should not be content to let statistics determine how much revenue certain tax rates would yield in the fiscal year 1929. I should want to have a hand in molding and making those statistics.

Federal Surpluses Invite Extravagance and Political Tax Cuts

Expenditures and estimates of expenditures are not cold and closed statistics. They will be less, other things being equal, the greater the opposition of the taxpayer. In the eight years 1920–1927, the so-called surplus of the Federal Government—as nearly as I can figure—averaged about $340,000,000 a year, and was $635,000,000 in the year 1927. Such surpluses are an open invitation to extravagance and to political tax cuts, by which I mean tax reduction based upon nothing more solid than a desire to win votes. The spender and the politician are awake with keen eyes and keener appetite, and in the long run the opposition of the taxpayer is an indispensable factor in holding them in check.

We touch at this point a subject-matter of great intricacy, in which it is not easy to discern the exact path of truth and wisdom. While the so-called annual "surplus" has averaged $340,000,000 in the eight years 1920–1927, inclusive, the average annual debt retirements during that period, according to my figures, have exceeded $850,000,000. In short, we have "paid down" the national debt each year by an amount much in excess of the "surplus." This excess apparently represents sinking-fund appropriations, payment of principal and interest from our European debtors, and miscellaneous funds available for debt reduction. In the years immediately following the war, large debt retirements were effected by the simple device of reducing the large working balance of the Treasury, which was built up to rather excessive proportions during the war. The so-called "surplus" represents in large part receipts from the sale or salvage of war supplies and the liquidation of various securities held by the Government; these receipts should naturally be devoted to the reduction of the debt and should not be counted in the "surplus" properly available for tax reduction. On the other hand, it is frequently forgotten that sinking-fund appropriations, charged against ordinary receipts, now exceeding $350,000,000 a year, and payments by our foreign debtors in respect of both principal and interest on their obligations to us, are used to retire our public debt. These sinking-fund appropriations and foreign debt payments amounted to $520,000,000 in the fiscal year 1927. If the Government's accounts were strictly balanced and there were no "surplus," we should still have $500,000,000 or more at the end of the year for the retirement of our public debt.

The real problem as I see it, however, is not one of statistics but of forces. At least four powerful figures are contending for the control of this large margin or surplus, whatever its exact size may be—the spender, the taxpayer, the politician (wanting unnecessary tax reduction to catch votes), and the saver, represented by President Coolidge, with Secretary Mellon, General Lord, and Congressman Madden in the immediate background.

Spenders and Politicians the Taxpayer's Real Antagonists

During the last eight years the "saver" has waged a magnificent battle, and if it were certain that he could continue to win I should add my counsel to those who are urging the taxpayer to abate the vigor of his fight. But in my deliberate opinion the spender and the politician will, in the next ten or fifteen years, win more victories than the saver. It is not a fight primarily between the taxpayer and the saver. The tax-

payer's real antagonists are the politician and the spender. The taxpayer cannot afford to lay down his arms in the belief that what he doesn't get the saver will.

TAX DISCRIMINATION AGAINST THE CORPORATION

Future probabilities are best estimated in the light of past events. It is my opinion that in the last five or six years the corporations of the country, through their comparative inactivity, have failed to secure reductions which were fiscally possible and which would have benefited not only themselves but the country as a whole. There has come to be an artificial and unjustifiable discrepancy between taxes imposed, respectively, upon incorporated and unincorporated business enterprises. A few unincorporated businesses pay higher taxes than they would pay if incorporated. But on the average, the reverse is true. According to recent estimates of the Treasury Department, if the corporations of the country were treated as partnerships (i.e., the stockholders paying as individuals on their distributive shares in the corporate earnings), the average rate of tax on the stockholders would be 9.10 per cent; whereas they actually pay, through the corporation, 13½ per cent and are subject in addition to surtaxes on distributed dividends which bring the total rate paid through both taxes to 15.27 per cent. This discrepancy between the individual and the corporation rates not only represents an illogical discrimination against the corporate form of business organization, but it has other unwholesome effects which cannot be discussed at this time. What I wish to emphasize is this: if the corporations had pressed actively for rate reduction in the Revenue Acts of 1924 and 1926, it is highly probable that the discrimination in question would, to a large extent, have been removed.

Taxes are as complex as life. Some politicians would mold taxes wholly in accordance with political expediency, but statesmen know that in the long run this would be impolitic. The socialists would tax only the classes and exempt the masses, but where this policy becomes supreme the classes migrate or melt into the masses. The moralist calls for just taxes, but taxes cannot be just. The administrator asks for simple taxes, but experience shows that they cannot simply be simple. The business man demands practical taxes, but financial history proves that it is impracticable to make them merely practical. The legalist wants taxes administered strictly according to law, but the records of the income tax and the property tax make it clear that such taxes cannot be successfully administered by methods meticulously legal.

Taxes do not merely happen; they are forged in the heat of a class struggle which, although ordinarily conducted within the bounds of decency and law, is none the less a struggle. Taxes emerge—to change the simile—as a resultant of these jarring forces; and no group of men is disinterested or scientific or wise enough to make tax laws for other groups without the active participation of the latter in the making thereof.

I go even further and insist that since the war some industries obtained tax reduction by insistence and pressure which deserved it less than other industries which actually received harsher treatment. To be specific, I believe that we should have a sounder and better tax system in every way if we had retained some of the war taxes on semi-luxuries which have been repealed, and refused certain deductions or exemptions within the income tax which have been granted to particular industries, using the proceeds to reduce the general corporation rate. The corporations as a whole permitted certain limited interests to obtain exemptions and reductions when the general body of corporations, in my opinion, had a better and sounder claim for a reduction.

The special classes in question were clamorous and insistent; they used their powers. I do not blame them in the least. So far as I know—with one or two unimportant exceptions—they worked for reduction by methods entirely legitimate. The point is, they worked while, comparatively speaking, the general body of corporations rested. However, it must be admitted that in one vital sense I am wrong in the statement that the special classes or interests in question obtained tax reduction to which other interests had a superior claim. I am wrong in the sense that the special interests took their cases to the legislative tribunals which decide such questions and won the verdict. Whether they would have won the verdict had other interests been adequately represented, is a moot question. They played according to the rules and they won.

PROMPTER SETTLEMENT OF INCOME-TAX CASES NECESSARY

Just as pressure is needed to force economy, so also it is needed to secure settlement of the more difficult tax cases and to collect the additional revenue which results from settlement. The Bureau of Internal Revenue in recent years has made a superb record in settling promptly the great mass of small and moderate-sized tax returns. But even in the auditing or administrative divisions of the Bureau (the Income Tax Unit and connected field offices) there were pending on October 7, 1927, 945,473 cases, of which 10,951 were cases for the taxable years 1917–1922, and involved some, if not many, of the largest corporations of the country.

The office of the General Counsel, the legal division of the Bureau of Internal Revenue, we are told by the Treasury Department, "is literally swamped with work." Each lawyer handling cases in litigation, apparently, is charged with responsibility for from 200 to 500 active cases. "On June 30, 1927, there were pending in the interpretative and penal divisions of the office [of the General Counsel] 808 income and profits tax cases, involving 1840 tax years, including claims, but exclusive of bankruptcy and receivership cases, insolvent, interest, and delinquency penalty compromise cases. The appeals division was charged with 18,481 appeals to the Board of Tax Appeals, covering approximately 32,000 tax years, and 48 appeals to the circuit courts. The civil division was charged with 2282 cases in suit and 255 cases for suit involving approximately 4323 tax years."[4]

The worst side of the picture, however, is still to come. On June 30, 1927, there were pending before the Board of Tax Appeals—the primary board of review and appeal in federal income-tax and estate-tax cases—18,313 undecided appeals, involving "deficiencies" (i.e., alleged additional taxes due) of $542,000,000. Petitions come to the Board far more rapidly than they can be decided, and "it has been estimated that the Board would be required to devote approximately four years—if no other cases were presented to it—to clear its docket."[5]

The figures and citations just quoted are from a recent "Survey of the Administration of Income and Excess Profits Taxes," prepared and submitted by the Treasury Department for the Joint Congressional Committee on Internal Revenue Taxation—a frank and illuminating document which deserves widespread circulation and careful study. It describes a situation which,

[4] Report of the Joint Committee on Internal Revenue Taxation: Survey of the Administration of Income and Excess Profits Taxes, p. 48. Washington, 1927.

[5] Ibid., p. 38.

despite intelligent and able administration—despite, in fact, heroic labor on the part of many employees of the Treasury Department and members of the Board of Tax Appeals—is a standing indictment against our political intelligence and our capacity for efficient administration. Reference will be made later to the challenge which this situation presents to the industrial and business interests of the country. At this point I wish only to stress my conviction that financial pressure would be the surest and quickest means of stimulating the kind of action necessary to clear up this congestion. Prompt settlement of these cases would yield hundreds of millions of revenue and leave everybody in the country better off—everybody, with the possible exception of certain tax practitioners.

Conflicting Interests of Industries in Tax Making

It follows from what has been said—and is otherwise obviously true—that the interests of the various industries in tax making are in partial conflict. In the past the farmers were, I believe, opposed to the repeal of the excess-profits tax; and organizations which appear fairly to represent the agricultural interests are now opposing the reduction of the corporation rate. The Treasury Department, acting in behalf of a well-rounded tax system, opposes the demand of the automobile manufacturers and proprietors of amusement enterprises for reduction of the excise taxes on automobiles and amusements. Conflict is of the essence of the tax problem, and certain aspects of this conflict are worthy of further note.

First of all, such conflict is inevitable and, because it is inevitable, should be frankly faced. It is much like the fact of sex. Incessant and unnecessary dwelling on the subject is only a little worse than priggish attempts to ignore it under all circumstances. To illustrate: Facts and studies which have come to my attention indicate that in most states the aggregate burden of state, local, and federal taxes bears more heavily upon farmers and public-utility companies than upon banking, manufacturing, and trading enterprises. This is not true in every state, but is, in my opinion, true in a majority of states. I may, of course, be wrong in this opinion, but at least the opinion is shared by most disinterested students of the subject. If it be a fact, the public utilities are entitled to plead this fact if and when serious proposals are made to increase their taxes.

The problem cannot—at least, should not—be avoided by log rolling. Industry A should not, either from mere complacency or from design, assist Industry B to get something which B does not deserve, in order to secure B's endorsement and support of A's just demands. Special exemptions and deductions, when not justified by the soundest considerations, act in the long run to increase the general burden of taxation. The point I am making is an important one. If industry generally, through good-natured complacency, remains silent when a special industry is asking for something it should not have, it will in the long run not only suffer by the exemption, but it will lose its influence in the legislative bodies which make and unmake taxes. I may illustrate once again. If industry in general at the present time shares Secretary Mellon's belief that we should keep the taxes on automobiles and amusements as a desirable supplement to the direct taxes—for the same reason that we keep the tax on tobacco—industry in some way should give voice to this opinion.

Common Interests of the Various Industries in the Simplification of the Tax Law and Improvement in Its Administration

The emphasis which has been laid upon conflict in taxation may create the impression that tax making is nothing better than a dog fight—a whirling battle of jarring sects and factions in which considerations of equity and sound public policy are lost to view. Fortunately this is not the truth. The very complexity of the fight sweetens it. There are so many issues and interests that, as regards any one, there are likely to be a large number of the participants unaffected, who crowd around the ring and frequently, if not usually, cast their votes as a disinterested jury. There are many important tax problems which can be settled right if any one is wise and ingenious enough to find the right solution. Here patient research and the disinterested mind that seeks the general as opposed to class welfare, find full scope for their beneficent services. Despite real diversity of interests, the various industries of the country have important interests in common which call for common counsel, a single organization, and united action.

These common interests or problems center about the simplification of the tax law and the improvement of its administration. One of these problems has already been described—that of inordinate delay in the final settlement of the larger and more involved tax cases. This problem is created largely by the legalistic idolatry of the American mind. We believe that there is in each tax case a precisely determinable legal liability, and that every disputed point should be finally decided by the Supreme Court of the United States. This belief or assumption does more credit to our hearts than our heads. We are worshiping false gods. In tens of thousands of income-tax cases there is no precisely determinable legal liability; and the income tax turns up new questions in such volume that no system of courts could possibly decide them. It has already been pointed out that there are nearly 19,000 unsettled appeals before the Board of Tax Appeals now. And some further idea of the complexity of the legal tangle involved may be gathered from the fact that the index maintained in the Division of Rules and Regulations of the Bureau of Internal Revenue, catalogs about 50,000 rulings or findings.

Delay in Tax Decisions a Major Evil Now Besetting American Business

The principal evil of delay is found in the uncertainty and apprehension which it inflicts upon taxpayers. It constitutes one of the major evils which now beset American business. In addition, it is very costly to the Treasury. During the long period in which these disputed cases are held up, many rulings or interpretations are changed by the courts, the Board of Tax Appeals, or the Treasury Department itself. The taxpayers who are benefited by these changes promptly claim refunds. But when the change affects a large body of taxpayers adversely, the Treasury Department is seldom able to collect the additional taxes to which it is entitled under the changed ruling. In several important instances of this kind, the Treasury Department has gone to Congress and asked to have the earlier and more lenient rule validated by retroactive legislation in order to avoid a wholesale campaign for the collection of additional taxes to which the taxpayers affected did not know they were liable. The Treasury has lost hundreds of millions in this way in the last four or five years. Change of ruling, in short, costs the Treasury far more than it costs the taxpayer.

I cannot pursue this question further except to express my conviction that the solution of this problem of delay is not, intrinsically or intellectually, one of unusual difficulty. It could be solved with two or three simple measures if a real will to solve it existed. We are blinded at present by traditional but outworn methods of procedure. The remedy lies in applying a few simple changes that the business man or the engineer would recognize after even superficial study. We need to see, among other things, that the application of a complicated direct tax, calling for the annual assessment of millions

of taxpayers, is a wholesale job and cannot be conducted after the manner of a lawsuit; that a prompt—indeed, in many cases, an advance—decision of disputed points is more important than any right of protracted appeal, provided such decision is made by thoroughly disinterested and competent men; and that if the Government cannot get and keep disinterested and competent men in its employ, we must either repeal the income tax or wallow indefinitely in the present slough of despond. I quote once more from the "Survey of the Administration of Income and Excess Profits Taxes:" "The collection of revenue is primarily an administrative and not a judicial problem. As far as the federal income tax is concerned, a field of administration has been turned into a legal battlefield." It is of this report that Secretary Mellon has written, "I agree unqualifiedly with the conclusions stated."

Delay and Uncertainty in Administration of Income Tax Largely Due to Constant Changes in Bureau Personnel

Much of the delay and uncertainty which characterizes the administration of the income tax is traceable to the constant change of personnel in the Bureau of Internal Revenue. In the highly important legal department of the bureau—now called the Office of the General Counsel—there have been nine successive heads since the outbreak of the war. There are only 11 attorneys who have served in this department for more than six years, and 52 attorneys have resigned from the department since July, 1924. In the Income Tax Unit there have been 4727 resignations of professional and technical officials during the last seven years. A. W. Gregg, the brilliant young attorney whose work in Washington has attracted widespread attention, recently resigned as general counsel after serving in that capacity for less than three years. It is rumored in Washington that C. R. Nash, generally recognized as the ablest administrator the Bureau of Internal Revenue has ever known, has handed in his resignation. In England his tenure of office would have been permanent during good behavior; he would have been given a salary equivalent to $15,000 or $18,000 a year in this country, with the assurance of a substantial pension on retirement; he would probably have been knighted—and he would have stayed in the government's service.

My time does not allow adequate discussion of this problem or of that presented by the dual organization of the field and collection work of the Bureau of Internal Revenue, in which there are 36 offices of "Revenue Agents in Charge" under Civil Service, and 64 offices of Collectors of Internal Revenue, not under Civil Service. The Treasury Department recommends a consolidation of these overlapping services and estimates that, with a single organization under Civil Service, 60 field offices could do the work now performed by 100 at a saving of approximately $2,000,000 a year. I can only point out here that these administrative defects are the source of great inconvenience and grave injury to the larger industrial taxpayers; that the business men of the country are particularly well qualified to devise ways and means of correcting these defects; and that if they would press their solution earnestly upon Congress, it would, in a comparatively short time, I think, be adopted.

Simplification of the Income Tax Highly Doubtful

Simplification of the income tax is an entirely different matter. Whether the income tax will ever be simplified is highly doubtful. Congress has tried it and failed. The tax experts have worked at it long and assiduously but have concluded that it is impossible. It must be recognized, they say in the recent report of the Joint Committee on Internal Revenue Taxation (p. 5), "that while a degree of simplification is possible, a simple income tax for complex business is not. The task is to simplify the law and the administration for all taxpayers so far as possible, without causing real hardship to those with complex sources of income and varied business enterprises who cannot be taxed justly under a simple elementary law." Here, it may be noted in passing, is another typical conflict in taxation—the conflict between justice and simplicity. As I have said in another place: "The historical fact is that modern states prefer equity and complexity to simplicity and inequality. The cry for equality and justice is louder and more unanswerable than the demand for certainty and convenience. . . . In the light of financial history, simplicity is a lesser god."

What the statesman and the tax expert have failed to do, perhaps the business man and the engineer can accomplish. The quest for simplification must go on. Where it will lead eventually, no one can tell. For certain classes of taxpayers, I feel confident that a simple law can be devised. For the others, if we cannot achieve simplicity, we may at least obtain comparative certainty. In the end a solution may possibly be found in some simpler and better substitute for the net income tax.

* * * * *

Industry's Most Important Task in Field of Taxation the Clarification of Laws and Improvement of Their Administration

In the year 1924, according to a recent statement by Secretary Mellon, federal, state, and local taxes paid by the corporations of this country constituted 24.58 per cent of their net income before deduction of taxes, and 54 per cent of the amount paid to stockholders in dividends. Taxes have thus become one of the major expenses of industry.

Under such conditions it is both inevitable and proper that the various industries of the country should endeavor actively to influence the form and burden of the taxes imposed upon them. This influence will naturally be exerted through a large number of separate organizations, representing restricted groups of industries, in each of which there is a substantial identity of interest. This diverse action is necessary, but it is not enough. There is urgent need for a more inclusive organization to coordinate and in part to check the activities of the more restricted groups; to give effective expression to the common interests of industry in the field of taxation; and to bring the strength of organized industry to the solution of public problems which apparently cannot be solved without its aid. I voiced earlier in this discussion the rights of the industrial taxpayer. I sound in conclusion the deeper note of his civic responsibility. Considering both what should be done and what can be done in the next ten years, the most important task and opportunity of American industry in the field of taxation is to work vigorously, through a specialized organization representing all branches of industry, for the clarification of tax laws and the improvement of their administration.

According to figures given out by Alfred Reeves, general manager of the National Automobile Chamber of Commerce, there were 23,125,000 motor vehicles in the United States in 1927, of which 2,985,000 were trucks. The production for the year was 3,066,000 cars and 464,000 trucks, 80 per cent of the former being closed cars, and the total wholesale value amounted to $2,556,750,000. Of the rubber output of American mills the automobile industry took 84 per cent, as well as 12 per cent of the country's copper output, and 14 per cent of the iron and steel manufactured. Over three million carloads of automotive freight were shipped over railroads during the year, and the consumption of gasoline was approximately 9.7 billion gallons.

The Mechanics of Materials—A Contribution from Applied Science to Pure Science

By H. F. MOORE,[1] URBANA, ILL.

DURING recent years we engineers have been frequently reminded of our debt to "pure" science, and of the necessity of the development of pure science if applied science is to continue its progress. These reminders have doubtless been good for us and we have come to realize (what we have always admitted) that the workers in applied science must keep in touch with the developments in pure science, because the advanced theory of today may be written into the handbook of tomorrow as an accepted working formula.

In this salutary mental attitude of recognizing our dependence on pure science let us not forget that while pure science furnishes us with generalizations of observed phenomena into concise, summarized statements which we call laws, and also gives us root ideas for many of the practical appliances and processes of applied science, yet it is equally true that the study of practical problems has been the source of not a few of the root ideas of pure science.

This is true to a very striking degree for the science which deals with the strength and elasticity of solids, the Mechanics of Materials. The speaker wishes to point out some of the contributions from applied science to pure science in their particular field, and to comment on them briefly.

Our sculptors and our architects look back to the days of ancient Greece as the golden age of art and of architecture. In those days, they say, men thought great thoughts, dreamed great dreams, and crystallized their thoughts and dreams into marble and stone. The applied scientist looking back at the same age sees much to admire, and recognizes several intellectual giants in his field, with the rugged features of Archimedes towering above all the others, but the applied scientist sees also how in those days the development of scientific thought and especially the development of scientific technique was limited and hindered by a spirit of intellectual aloofness which caused the man of thought to look down on the world of tools and labor.

We find this spirit playing no small part in shaping the life and writings of Archimedes, whom we hail as the father of all engineers—a title which probably makes his ghost highly indignant. This influence is discussed by Plutarch in his comments on Archimedes in the life of Marcellus.

The men to whom the next important advances in the science of mechanics were due, are Gallileo, Robert Hooke, and the French engineer Navier, who was the first to present the theory of beam action in the general form it has retained ever since.

The speaker believes that he is not going too far when he claims that in the development of the science of mechanics of materials the influence of the engineer has been the major factor.

So much for the past; how about the present? In the science of mechanics of materials, is applied science still an important source of ideas and concepts for the development of the "pure" science? Two present-day problems in that science will serve as illustrations.

A question of primary importance, still undecided, concerns the cause of structural failure in materials. Is such failure due primarily to excessive internal forces—to *stresses?* Is it due to excessive distortion—to *strains?* Is it due to a tendency to excessive internal slipping action—to *shear?* Or is it due to excessive internal stored *energy?* Each of these theories has been held to be the cause of failure, and all with the possible exception of the first-named, stresses, have advocates today.

There is not time to review, even in outline, the experimental study of this problem; suffice it to point out that the names of engineers are outstanding in the literature of this problem. There is Guest, the advocate of the shear theory, who began his work in this field about the time he was professor of applied mechanics at Worcester Polytechnic Institute; Hancock, professor of applied mechanics at Purdue, who later was at Worcester; Becker, professor of applied mechanics at North Dakota, who as a graduate student at Illinois contributed an interesting study showing the importance both of shear and of strain; Haigh, metallurgist and engineer at the British Royal Naval Academy at Greenwich, who is the outstanding advocate of the energy theory; and Matsumura and Hamabe of the engineering department of the Kyoto Imperial University in Japan, who have done pioneer work in studying the failure of brittle metals.

The role of prophet is a fascinatingly dangerous one. The speaker cannot resist the temptation to attempt that role and to make a prediction of a division of the science of mechanics of materials which he thinks will assume major importance within the next generation, and also a prediction that engineers will take a prominent part in its development.

Two practical problems are the forerunners of this division of the science. For some years oil-well drillers have found their long steel drill rods breaking at places where stress and strain were supposed to be small, and they have been much puzzled thereby. A few years ago users of steam turbines were much disturbed by failures of the disk wheels of turbines which seemed to be caused by sidewise "fluttering" at certain critical speeds. There used to be a saying that if he hit just the right note a fiddler could "fiddle down a bridge"—and while so far as the speaker knows, no bridge failure has ever been caused in this way, yet it did seem that in these turbine disks there were failures caused by "tuned" vibration.

Now in both the long drill rods and in the turbine disks we face the problem not of *static* balanced stress, but of *kinematic* stress with interference of waves of stress and resulting high stress in unexpected places. Students of acoustics and of earthquake waves have given hints concerning this problem, but the speaker is of the opinion that the science of kinematics of stress, and of stress waves, is one which is at present in about the same stage of development as was the science of static stress before the days of Navier and Saint Venant, and he further believes that engineers working in engineering laboratories will have a large share in its development.

In support of this last claim there may be cited the work of the late Wilfred Campbell on the mechanics of stress in a rotating turbine disk. This work was done in the shops of the General Electric Company and involved both careful work in the study and much "mean and manual labor" in experimentation. Plato would certainly have been shocked and alarmed at the conditions under which Mr. Campbell carried on his beautiful and delicate studies of rotating and fluttering disks. He solved a special problem in the kinematics of stress, and left as his monument what the speaker believes will be recognized as an important piece of pioneer work in a new division of the science of the strength of materials.

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Extracts from an address at a joint dinner of Sections M and C (Engineering and Chemistry) during the Annual Meeting of the A.A.A.S., Nashville, Tenn., December 28, 1927.

What the National Engineering Societies Can Do for Engineering Education

By W. E. WICKENDEN,[1] NEW YORK, N. Y.

WE HAVE now had four years of scrutiny of engineering education. This has been done at the instance of the colleges themselves and in large measure through their agencies, yet it has not been entirely what the underworld would call "an inside job," for the industries and the national societies have had an important part in it. From its origin, its auspices, and its methods, this kind of investigation can hardly be expected to lead to revolutionary changes. We should all like to see engineering education improved, but it is much too good to hand over to the wrecking crew. In fact, it is essentially sound. We may with reason go much farther and assert that for consistency of purpose, stability of organization, fitness of means to ends, absence of shoddy qualities, and ability to bend without breaking under the stress of changing conditions, its record in the past 100 years is fairly unrivaled in the annals of American education. During the past twenty-five years, however, it has not succeeded in making itself interesting to the American public.

Engineers are realists and are not easily led in search of educational Utopias. It is a safe premise that progress must begin with the means at hand, and proceed through evolution. We should be quite content with the results of the investigation if we can bring this evolution under fairly rational control. That is more than can be done from the inside by educators alone. One of our major objectives has been to prepare the way for a larger share by engineers and industrialists in shaping the policies and practices of engineering education, in carrying on its operations, and in promoting its adequate development. There are many reasons I might urge on you to support the idea that the national societies should share these responsibilities. I shall select only two: one is a matter of ancestry; the other, of posterity.

What Can Be Done

1 Act jointly—pool your interest with sister societies and colleges.

2 Take active measures to guide American youth in its consideration of careers.

3 Create a joint accrediting agency for colleges of engineering.

4 Reexamine and, if practicable, codify your rules of admission to membership.

5 Through student branches educate students in the history, traditions, ethics, and social functions of the engineering profession.

6 Create joint sanctions for the award of professional degrees, and relate them to terms of admission to professional grades of membership.

7 Take a large share in directing the after-college education of young engineers.

8 Certificate the educational and professional attainments of engineers within the profession.

9 Take measures to create other credentials of educational attainment in addition to college degrees.

10 Do your part, through joint agencies, to promote the corporate welfare of engineering education.

Engineering Societies Originally Agencies of Education

There are two fountain heads of tradition in which to seek the primary or original purpose of our professional societies, the Institution of Civil Engineers in Great Britain, and the Verein Deutscher Ingenieure in Germany. It is said that most of the founders of the Institution of Civil Engineers were constructors of machinery, so no one may question the legitimacy of your descent. The significant thing is that these parent societies came into life as essentially educational institutions. In the official account of the founding of the I.C.E. you may read:[2]

> It was toward the end of the year 1817 that a few gentlemen, then beginning life, impressed by what they themselves felt were the difficulties young men had to contend with in gaining the knowledge requisite for the diversified practice of engineering, resolved to form themselves into a society.

At the first meeting in January, 1818, an address delivered by the vice-president, a Mr. Palmer, indicates that the Institution was founded in response to the need felt of

> a source of information or instruction for persons practicing Civil (i.e., civilian) Engineering;

and the object as expressed by the founders was

> facilitating the acquirement of knowledge necessary in the civil engineering profession and promoting mechanical philosophy.

The story of the Verein Deutscher Ingenieure, as told by its present secretary, Dr. Conrad Matschoss,[3] recounts that back in the 40's young students in the old Gewerbeinstitut of Berlin formed an association to combine mutual technical advancement with a friendly community life. They gave to their student Verein the homely name of Hütte, or cottages, since the Hütte were intended to be a home for those studying at Berlin, far from home. At the same time the Hütte were to be workshops in which, through their own efforts, technical knowledge and ability might be developed among the members. In the 50's they began to question in the circles of the Hütte, if and in what way similar Hütte could be built in various parts of Germany for young engineers who went from the Gewerbeinstitut into practice in their first positions, to care for their intellectual progress and create a fellowship in striving for a common goal. Out of this effort to extend the Hütte grew a plan for a Verein Deutscher Ingenieure. It is said that the organizing convention drew together more than one hundred young members, virtually students, and about twenty older men, including the founders of the original Hütte. Thus it was literally true that the V.D.I. arose as a fraternity of students and novices, to be an auxiliary to their professional training.

The Engineering Profession Should Contribute More to the Guidance of Youth

So much on the side of ancestry; now let us turn our attention

[1] Director of Investigation, Society for the Promotion of Engineering Education.

Lecture delivered at the Annual Meeting, December 5 to 8, 1927, of The American Society of Mechanical Engineers.

[2] Trans. Inst.C.E., vol. 1 (1836), Introduction.

[3] "Verein Deutscher Ingenieure, 1856–1926; Aus des Geschichte des Vereines deutscher Ingenieure," by Dr. Conrad Matschoss.

to posterity. A professional organization is a form of group citizenship. It creates a special status for its members, secures for them a unique recognition by society, enforces certain forms of social morality, and makes certain collective contributions to social well-being. The prestige and effectiveness of a professional organization are in direct ratio to the quality of its personnel. It is easy to observe that collective action does not make a group of small men function as supermen. This principle is widely accepted by the American people, which increasingly ranks the professions on a scale of their educational qualifications. It is literally a fact that the personal standards of the engineering profession are now being determined by selective processes which operate in high schools and colleges. That was not true forty years ago, when probably less than a quarter of your members held college degrees. Today more than two-thirds of the accessions to the national engineering societies hold college degrees, and more than four-fifths have had a substantial amount of college training. Go back one step further and you will find that half of these young men decided to enter engineering before their last year in the preparatory school, and three-quarters of them before their graduation. Furthermore, you will find that less than a quarter of them made this decision on adult advice, and that a large proportion of them went it blind in response to the appeal of engineering work to boy nature. If you desire to build up the engineering profession and strengthen its position and influence, there is where your job begins.

A study of the conditions under which young men choose an engineering career and are drawn to an engineering college would convince any one that the profession ought to contribute more to the guidance of American youth. Engineering suffers about equally from the tin halo of romance in current fiction and movies, and from lack of public insight into its real magnitude and responsibilities. Betterment is needed along both general and specific lines. Engineers are needed as speakers and counselors in secondary schools, and the profession at large might well sponsor sound institutional publicity—but not propaganda—aimed in part at the boy making a choice of career and in part at his adult advisers.

Views of the Engineering Profession on Educational Policy

It was a recognition that the professional societies have a vital stake in engineering education that led to a series of special inquiries by the national bodies of chemical, civil, electrical, mechanical, and mining engineers. The A.S.M.E. led the way and deserves a large measure of credit for the project. In all, about 2000 of the more influential men of the profession were consulted; nearly 1200 replied, and 1060 sent replies in time and in form to be compiled and analyzed in detail. If you have worked with questionnaires you will recognize that a gross return of 60 per cent and a net compilation of 54 per cent are extraordinarily high. I mention this fact as evidence that the men who shape the sentiment of the engineering profession are thoroughly awake to the importance of engineering education. The quality of the replies testifies to the capacity of leading engineers to take a constructive share in shaping engineering education, quite as strongly as the number of replies testifies to their desire.

The engineering profession in America has never formulated a policy concerning the recruitment and training of its future members. In this respect, at least, it has remained behind the professions of law, medicine, architecture, dentistry, and the major branches of the religious ministry. Its guiding traditions, largely inherited from British sources, have been those of an open profession, entered through a novitiate of practical experience to which formal scientific training is a desirable but optional auxiliary. While these traditions have been retained in principle, in reality they have been largely reshaped by changing conditions. The profession at large has accepted these changes passively. Probably it has not yet attained to the stage of unity and self-consciousness where it might attempt to shape and announce a formal educational policy. The data of these five inquiries, more than any other materials yet assembled, reduce the attitudes of the profession at large to an orderly basis, in which a fairly definite policy is implicit.

Engineering is regarded as an open profession, accessible to both self-educated men and men of formal scientific culture. College training is accepted as the first normal step to professional standing, but experience in subordinate capacities under the guidance and criticism of qualified practitioners is an indispensable part of an engineer's training. Engineering is seen as a broad function in social economy with varied types and grades of responsibility. No single procrustean program of training, as in medicine or dentistry, can meet the varied needs of engineering. A variety of types of education and of institutions ranging in character from the vocational to the professional should be provided. There can be no single, standard length of program, but four years in college is tacitly accepted as a reasonable period for the average man. These engineers would limit formal teaching in advance of responsible experience largely to the underlying principles of engineering, its methods of analysis, its verbal, symbolic, and graphical language processes, and its setting in contemporary civilization. They deem it impossible to reproduce engineering problems as a whole, with their inseparable economic and administrative complications, in the artificially simplified setting of a school. They recognize that professional preparation may be begun in school, but must be completed in practice. The principal programs of studies should be differentiated from each other to a moderate degree only in order to assure concentration on a logically related core of subject-matter and bring the student's efforts to a focus, but actual specialization should largely be deferred to the years after graduation, either in the graduate school or in practice. Curricula should be built up from humanistic, scientific, and technological materials of a basic character, and include as a common foundation a substantial core of English and economics, mathematical and physical science, and the scientific bases of engineering technology. The economic aspects of engineering, as well as the technical aspects, deserve considerable emphasis in all distinctly engineering subjects. The quality of engineering education is determined primarily by the qualifications and effectiveness of teachers and the endowments and preparation of students rather than by curricula and equipment. Teachers should have both scholarly preparation and professional experience, and should be in active touch with engineering practice. As far as practicable, students should be selected for aptitude as well as scholastic attainment. The national engineering societies should exercise a guiding influence upon the schools, but not undertake to impose on them a formal scheme of standardization. This statement is about as close to a declaration of policy as the data at hand will take us.

Influence of the Profession upon Engineering Education

The issue of greatest moment presented by the five inquiries was the question:

> *Should the engineering profession, through the national societies, exercise a more direct influence upon engineering education?*

By way of background, it will be recalled that the development of engineering colleges in America, from the days of Amos

Eaton of Rensselaer to the present, has been almost exclusively directed by professional educators. Unlike the schools of medicine and dentistry, which grew out of and finally displaced a scheme of pupilage, the engineering colleges have never been largely dominated by practitioners or the professional body. They have been free to develop on broad lines, with programs which combine humanistic, scientific, and technological elements, and have not been confined to a narrowly technical discipline. Whatever standardization exists the schools have imposed upon themselves, largely through a process of imitation. On the other hand, there has been little fostering of the schools by the profession in its corporate sense. No protection has been thrown around substantial standards, and no moral pressure brought to bear on institutions of uncertain quality. The attitude has been cordial, but essentially aloof. The engineering societies have not consistently recognized the work of the colleges as a substantial step in professional preparation; in one case graduation from an arduous four-year course carries the same weight toward membership requirements as one year's experience in installing conduit and wire for an electrical contractor.

This detachment of colleges from the organized profession has spared us from the evils of arbitrary standardization, but it has also cost both parties much that would have been for our good. The answers to the direct question were evidently weighed with care. There was no provision for painless replies by checking a choice between "yes" and "no." Answers had to be formulated and written out. This feature doubtless tended to reduce the proportion of replies, though many may have felt unprepared to meet the issue or unable to visualize the steps through which a favorable answer might be given effect. Notwithstanding, nearly two-thirds of the 1060 did make direct replies, and the ratio of those who favor a more direct influence to those opposed is practically *nine to one* (see Fig. 1).

The comments indicate shades of opinion quite as significant as the categorical replies. Here are a few of the emphatic endorsements:

> The engineering societies could not be engaged in a better or more laudable work. The societies are eminently qualified to serve and should exercise a direct influence in educational matters.
> (Consulting civil engineer)

> Emphatically yes! The profession can advance but poorly under the tutelage of inferior vision or cloistered technology.
> (Construction engineer)

> Yes, in helping to develop some plan whereby such education, cost, and effort is not wasted on poor material not qualified for engineering work.
> (Chief electrical engineer)

> Yes, this is of vital concern to the future of the profession, and the engineering societies should consider it a duty and obligation.
> (Consulting mechanical engineer)

> Very important not only for the profession but for the industries in general.
> (Vice-president, manufacturing company)

> The national societies should be the medium through which the engineering profession should attempt to promote and guide engineering education.
> (Research engineer)

Other endorsements were guarded by warning against intrusion or imposed standardization, and suggested that the influence of the national societies should be purely advisory:

> Yes, in helping us to estimate long time results and prospective needs. But, for the Lord's sake, don't presume to tell us how.
> (Dean, engineering college)

> The influence should be to inspire and guide, not to dictate.
> (Editor)

> If the engineering profession through the Societies indicates the qualifications or education necessary for a successful career, then the colleges through their professors will meet these requirements. This should be left to the colleges to work out.
> (Civil engineer)

There was still another group which expressed emphatically an attitude of "hands off:"

> No. I do not believe this is the natural function of such societies.
> (Electrical engineer, railroad)

> I feel that professional opinion is so unformed that it can have but little effect on the colleges.
> (Transportation engineer)

> The mass of the members will not participate and the activities will gravitate to the control of a small group of doctrinaires who will use the Society to promote their own notions.
> (Chemical engineer, lead company)

Taken in the large, the replies to this direct question, backed by the response to the inquiries as a whole, stand out as an unequivocal mandate by the profession. I think I may safely say that the colleges welcome this mandate. Educators want more guidance and backing from the profession. They sense the need of solidarity. Cooperation between divided societies and scattered institutions is difficult. Effective relations between professional societies and colleges must be group relations. Those who understand the educational problems best ought to supply much of the initiative, which ought to be sustained and consistent. Transient agencies do not meet these conditions. With these ends and needs in view, the colleges are making adjustments in their own organization to adapt it to permanent liaison and team work with the professional societies. Assuming that we can each adjust our machinery to the common task, can we actually work out a partnership in engineering education?

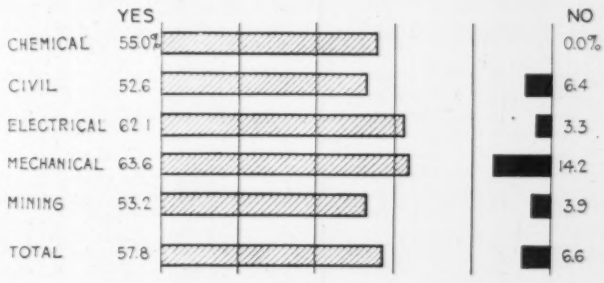


FIG. 1 SUMMARY OF REPLIES TO QUESTION WHETHER ENGINEERING PROFESSION, THROUGH ITS NATIONAL SOCIETIES, SHOULD EXERCISE A MORE DIRECT INFLUENCE IN ENGINEERING EDUCATION

Probably we shall have to begin by constituting a joint national committee on engineering education, with representation for the principal societies and the colleges. As a pragmatic matter, it will probably be easier to set up such a committee if it can be made only a nominal source of expense to the sponsoring societies. The staff services needed to make its work effective would need to be provided for largely by the educational side, and measures anticipating this plan are now taking form. A joint national committee might reasonably begin by putting the present relations between the societies and the colleges on a clearer basis. The societies enroll student members, have affiliated student branches or chapters, and credit graduation toward membership requirements. These privileges are restricted by formal rules to students or graduates of "accepted" or "recognized" institutions. These regulations are vague in definition and are applied in a confidential, discretionary manner.

The result of this vagueness is that the engineering profession

has exercised virtually no open influence in creating or sustaining high educational standards or in guiding the public to discrimination between distinguished, sound, marginal, and deficient institutions styling themselves alike as "colleges of engineering." The profession has exercised no check on the spread of low-grade institutions and the bestowal of degree-granting privileges. It has done nothing to create a fair balance between the more extensive and the more intensive types of training. In these respects its attitude has differed markedly from that of other strong professional bodies. It seemed pertinent, therefore, to extend the question concerning the influence of the profession

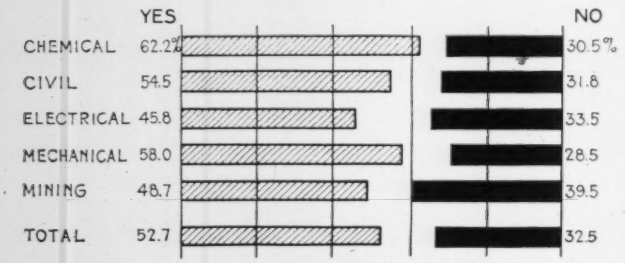


FIG. 2 SUMMARY OF REPLIES TO QUESTION WHETHER THE A.S.M.E. SHOULD MAINTAIN A LIST OF INSTITUTIONS WHOSE GRADUATES WOULD BE ACCEPTED FOR JUNIOR MEMBERSHIP AND IN WHICH STUDENT BRANCHES WOULD BE RECOGNIZED

upon engineering education somewhat further into particulars, thus:

> *Specifically, and as one means of exercising a direct influence on engineering education, do you believe that the A.S.M.E.[4] should maintain and publish a list of approved institutions whose graduates would receive credit for a substantial part of the requirements for membership and in which student branches would be recognized?*

Fig. 2 gives you a summary of the answers. No information was supplied to indicate the degree of need of such protective measures. As a matter of fact, there has been a fairly rapid growth in recent years of weak or marginal institutions and a disconcerting shift of enrolment toward institutions of that character. Each engineer was left free to estimate the degree of exigency for himself. Many were non-committal, as you observe. A decisive plurality of each group and a slight majority of the whole number registered in favor of a list of approved institutions. The ratio of approval to disapproval was 2 to 1 among the mechanical engineers and 1.6 to 1 among all groups combined.

Next followed the contingent question:

> *If so, on what principle should such a list of approved institutions be drawn up?*

Items were suggested so that a choice might be indicated by checking. Answers to this contingent question were confined almost wholly to those who had approved the plan in principle. (See Fig. 3.) Practically all of these answers favor taking account of the total graduation requirements; over ninety per cent would take account of qualifications of the teaching staff; more than seventy-five per cent the requirements in the major branch of engineering, and seventy per cent the requirements for admission; but only a minority of those who favor creating an approved list would take into account the physical or financial resources of the college. In short, a sound course of study and a well-qualified staff, and not plant or endowment, are ranked as the primary qualifications. The informal comments recognize the delicacy of the problem. Many point out that the selection of approved institutions would require careful investigation and great discrimination, that the societies alone are not set up to handle a problem of this nature, and that great care would be needed to keep the whole matter from becoming perfunctory and therefore valueless. Considering the unforced nature of the verdict, the radical departure from a traditional policy of *laissez faire* suggested, and the admitted difficulties to be overcome in giving it effect, the favorable attitude on the accrediting of institutions seems to carry much weight. The successful handling of this matter would seem to call for a pooling of interests by the national societies and their close cooperation with the Society for the Promotion of Engineering Education. This would be a specific job for a joint national committee. It should be made clear, even emphatic, that no desire has been indicated for any rigid standardization of education or any such classified rating of institutions as that applied

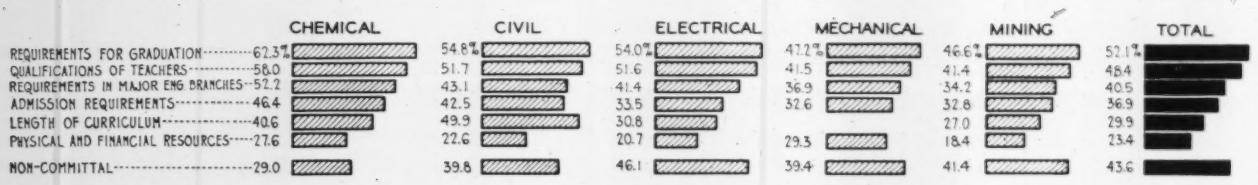

CHEMICAL CIVIL ELECTRICAL MECHANICAL MINING TOTAL
REQUIREMENTS FOR GRADUATION 62.3% 54.8% 54.0% 47.2% 46.6% 52.1%
QUALIFICATIONS OF TEACHERS 56.0 51.7 51.6 41.5 41.4 48.4
REQUIREMENTS IN MAJOR ENG BRANCHES 52.2 43.1 41.4 36.9 34.2 40.5
ADMISSION REQUIREMENTS 46.4 42.5 33.5 32.6 32.8 36.9
LENGTH OF CURRICULUM 40.6 49.9 30.8 27.0 29.9
PHYSICAL AND FINANCIAL RESOURCES 27.6 22.6 20.7 18.4 23.4
NON-COMMITTAL 29.0 39.8 46.1 39.4 41.4 43.6

FIG. 3 SUMMARY OF REPLIES TO QUESTIONS DEALING WITH POINTS TO BE CONSIDERED IN PREPARING A LIST OF APPROVED EDUCATIONAL INSTITUTIONS

by professional bodies to schools of medicine and dentistry. Reasonable minimum specifications for the recognition of an institution as "a college of engineering," intended as a safeguard to the public and the engineering profession, stand approved in principle. The plan is actually not a radical one, for there is scarcely any division of higher education, other than that of engineering, which does not now have some accrediting agency.

A joint national committee on engineering education might well make a study of the regulations of the national societies which govern admissions to membership. These rules were evidently drafted with a view to preserving the tradition of an open profession with its emphasis on experience as the primary element in preparation and on responsible performance as the primary test of professional standing, and with a view to avoiding any appearance of discrimination in favor of college men. These rules now vary considerably and might be codified to advantage. The A.S.C.E. now grants four years of credit for the completion of a course in civil engineering or architecture in a school of "recognized standing," while the A.I.E.E. considers graduation from the electrical course as equivalent to one year's electrical experience, which, for aught to the contrary, may mean installing conduit and pulling in wire. A more uniform plan, based on recommendations by a joint national committee, would help the profession to present itself to the educational world in a more consistent, and possibly a more favorable, light.

The student chapters and branches offer the societies one of their most useful channels for constructive service. It has been

[4] The names of the several societies appear on separate questionnaires.

a pleasure to observe the increasingly constructive measures taken by the societies in fostering these student groups. In line with the policy of making these groups effective educationally, I should like to suggest that more be done by the parent societies jointly to present to students the history, traditions, ethics, and functions of the engineering profession. At least one lecture of this nature a year in each institution, delivered by one of the distinguished leaders of the profession, and made a notable event under joint auspices, ought to be a reasonable minimum goal.

THE QUESTION OF ENGINEERING DEGREES

Next we come to a delicate problem involved in the award of professional degrees, such as Civil Engineer, Mechanical Engineer, and the like. The custom of nearly one hundred years grants this privilege to the colleges and makes it something of a vested interest; but the professional body has a stake in the matter, for degree-granting privileges are often bestowed indiscriminately by the states, and the public is prone to accept a professional degree as an authentic label. There is little if any prospect that the colleges will give up this prerogative. Better regulation is plainly desirable, with more definite sanctions from the professional body.

Most of the colleges have come to recognize that the award of a professional title for a purely scholastic undergraduate course of studies is at variance with the fundamental traditions of the profession. Seven institutions still follow this practice, however, and three of them are old and prominent institutions. Five institutions offer the professional degree for a cooperative undergraduate course which includes considerable rudimentary experience, and seventeen offer it as a post-graduate degree for advanced studies in residence. A few institutions make no provision whatever for the award of the professional degree. The majority award the bachelor's degree at graduation, and offer the professional degree after a period of practice ranging from two to seven years, on presentation of a thesis and other credentials.

This confusion is the national societies' opportunity. Let us have a joint committee of these societies and the Society for the Promotion of Engineering Education draw up recommendations which have the joint sanctions of the professional body and the colleges, and let us use our moral suasion to promote their gradual adoption. This is a matter in which the majority of the colleges will welcome the guidance of the profession.

POST-COLLEGIATE EDUCATION

Closely linked with this problem of professional degrees is the problem of continuation of education after college. To put the case briefly, we need broader and more extended education for engineers; our present college programs are overcrowded and need to be lightened; most of our students have to live within a restricted income of time, incentive, and expense; we can meet the problem of only a minority, perhaps 15 to 25 per cent at the most, by keeping young men longer in colleges as full-time students; and we must find our answer, for the most part, by carrying over more education into the early years after college. These years are a period of relative leisure—the hours of employment are often short and the duties are relatively rudimentary and often do not demand in full the mental powers employed while in college. Some one has called the change on leaving college a shifting of mental gears from high to low, often hard on the gears. From the educational viewpoint this is a period of maximum latent opportunity. The student is at last in contact with reality; he is making a definite orientation to his career, he is developing specialized tastes and needs, he is becoming socially and economically responsible. Educational possibilities open up at this stage which were not fully open in college. Business training can be given to better advantage, industrial organization and economics can be made realistic, technical specialization can be undertaken in earnest, and advantage gained from the vast stores of experience in the minds and records of industry not available to the colleges.

Plainly, it would be very difficult for the colleges to meet this problem alone. A few urban institutions doubtless have a great field of opportunity, but the majority of graduating classes scatter widely, graduates pass out of college jurisdiction, the technique of educational absent treatment is not well developed, the incentives to which the colleges may appeal are weakened, and there are no suitable credentials for educational attainments out of the regular college routine. Is not this after-college education a realm of responsibility for the national societies? Let me remind you again of the origins and early traditions of the Institution of Civil Engineers and the Verein Deutscher Ingenieure, organized for the nurture of young engineers passing through the novitiate in practice. It would be but a swing of the pendulum to its original position for the national societies to undertake to foster the post-college education of young engineers. Some one has said of modern boyhood: "When my father and my mother forsake me, then the Boy Scouts will take me up." With a slight change, it might read, "When my Alma Mater forsakes me, then the national societies will take me up." Why should not this process of after-college education be tied in with the award of professional degrees? Would it not be appropriate for the colleges and the engineering societies to maintain some form of joint tribunal, before which the young engineer would place his credentials at some suitable period after graduation for appraisal, under some reasonably strict and reasonably elastic code of specifications? If the record of experience and educational attainment was found satisfactory a certificate might be granted which would testify to his eligibility to receive a professional degree with the joint sanction of the profession and the colleges, and to his eligibility for professional membership in a national society.

CERTIFICATES OF EDUCATIONAL AND PROFESSIONAL ATTAINMENT

This proposal means nothing less than that the professional body itself should seriously undertake to certificate its membership, and not let this function pass by default into a routine form of public licensure, little calculated to raise the profession in public dignity. Should the profession assume this responsibility toward the college-trained contingent, it would be morally obligated to do the same for its other members. This raises a question—what form of credentials of educational attainment other than college degrees should be provided, and by what means? Let me point you to British example. The university degree is more closely safeguarded there than with us, yet is accessible to any man who makes the required preparation by any means whatever. Any man whose education has been irregular or informal may qualify for a degree by passing the matriculation and degree examinations of the University of London. The British institutions of mechanical and electrical engineers join officially with national boards of education in England and Scotland in granting National Certificates and National Diplomas for approved technical courses, many of them given in the evening. The several grades of membership in the British institutions of engineers are based on real examinations and are in themselves very substantial credentials of educational attainment. In our own situation two needs stand out strikingly: (1) some form of educational credentials, national in value, other than a college degree, for substantial technical education of a briefer and more intensive character, and (2) some recognition of attainment for non-college men of real professional caliber. There is

no ready-made prescription for these problems, but they might well be studied in detail by a joint national committee on engineering education.

RESPONSIBILITY OF PROFESSION FOR SUPPORT AND DEVELOPMENT OF ENGINEERING EDUCATION

Finally, it seems fitting to point out the responsibility which rests on the organized profession to lend aid to the adequate support and development of engineering education. The unexampled prosperity of medical education and the millions of treasure being poured into it may well give engineers pause. This condition is easily traceable to the fact that some agency outside of the schools has undertaken the task of promotion. There is no social agency, outside of the engineering schools themselves, at work today promoting the general welfare of engineering education. Industry and the profession are both cordial, but they are inactive. From their beginning to now, engineering schools have been purely educational enterprises, promoted by educators, and promoted separately. The responsibility of the profession as an organized body relates to the corporate prosperity and development of engineering education. The total neglect of this interest in America is in striking contrast to its active cultivation abroad under government auspices. The problem is not wholly one of providing adequate financial support, though that is important. An equally important matter is the task of making the professorship attractive to men of the highest qualities. It can be done, for Germany has done it, but the combined efforts of the government, industries, professional bodies and schools have been needed to accomplish and sustain this end.

We have many problems needing teamwork. Engineering educators, sensing the need for a nucleus around which this teamwork may develop and out of which sustained initiative may flow, have drafted plans for a Foundation for Engineering Education, to be auxiliary to their national organization and to provide support for staff services and for joint activities with professional and industrial bodies. Engineering education can be bettered in details by the efforts of the colleges acting alone. It can be made adequate to its task in American life only when it becomes a part of far-seeing plans for the development of our profession and our industries.

SUMMARY

There was once a Scotch divine who was asked the secret of good preaching. He replied that the secret is threefold: "First you tell them what you are going to tell them; second, you tell them; and third, you tell them what you have told them." Acting on his last injunction, these are the things I have told you:

1 Act jointly—pool your interest with sister societies and colleges.

2 Take active measures to guide American youth in its consideration of careers.

3 Create a joint accrediting agency for colleges of engineering.

4 Reexamine and, if practicable, codify your rules of admission to membership.

5 Through student branches educate students in the history traditions, ethics, and social functions of the engineering profession.

6 Create joint sanctions for the award of professional degrees, and relate them to terms of admission to professional grades of membership.

7 Take a large share in directing the after-college education of young engineers.

8 Certificate the educational and professional attainments of engineers within the profession

9 Take measures to create other credentials of educational attainment in addition to college degrees.

10 Do your part, through joint agencies, to promote the corporate welfare of engineering education.

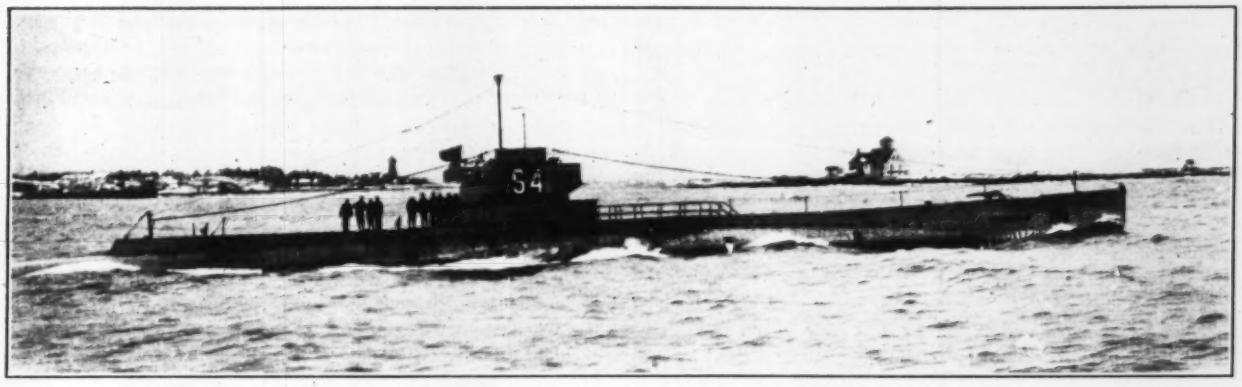
Necessity of Recording Standards in Machine-Tool Design

THE need for standards in the engineering field was recognized at the very start, and with very good reason, for standards are blazes on the trail of progress without which we lose all advantages of experience and laboriously explore the same ground over and over, traveling often in circles, instead of advancing steadily toward that perfection of design which is our ultimate objective.

In the early days a great deal of pioneer work was done in the engineering field in determining the underlying principles of design which formed the basis of our present standards, but time and again the conclusions arrived at, the truths discovered, have been lost and forgotten through the lack of established standards to mark the advance over previous practices which had been accomplished. They say there is nothing new under the sun; that may or may not be true, but by the use of standards we are at least trying to make certain that whatever advancement is made in design, or in methods of manufacturing, or in the economic use of machines, is preserved and recorded in such form as to be immediately available when needed.

Standards are an aid to the engineer, not a hindrance. They enable him to start out with a record immediately available to him of the best practice that has been derived from all the experiences of the other engineers in his company. This prevents him from making useless experiments that others have made before him and enables him to proceed with confidence. He can concentrate his attention on the broader aspects of his machines, knowing that the minor elements which he uses have been tried and tested by frequent applications.

As an example of what I mean, I may mention a little incident which occurred during this summer at our own factory. One of our research engineers had been making a rather extended study of the amount of power required to operate handwheel drives furnished on several different machine tools. While in the midst of his investigation he happened to ask my opinion as to what was the best practice in this respect. I was surprised to find that we had apparently no established standard practice in this respect, although I remembered very distinctly that my father years ago had worked out this problem very thoroughly. I even remembered that he had adopted for himself an unrecorded standard of 15 lb. starting torque as the best basis for the design of these handwheel drives, all things considered. When I had explained this to the engineer, he startled me by announcing the result of his investigations, saying that he had found in our own shop on different makes of machines, handwheels requiring anything from 15 lb. up to 40 lb. It requires no very great imagination to realize how tired a machine operator would become if he had to operate a handwheel requiring a 40-lb. pull many times during the day. I simply give this to show how easy it is to lose the results of such a research unless it is established in a formal way as a standard, once the best practice has been established.—J. E. Gleason in a paper before the First Machine Tool Congress, Cleveland, Ohio, Sept. 19–22, 1927.



THE ILL-FATED S-4 UNDER WAY

Submarine Safety and Salvage Devices

Safety Weights—Detachable Chambers—Diving Suits—The Extensible Tube—Signaling Buoys—Watertight Compartments—Means of Attaching Lifting Chains or Pontoons to a Submarine—Submarine Salvage Vessels—Conclusions

A FACTOR of safety in military engineering means a vastly different thing from what it does in civilian engineering. In the latter it means a leeway in the ability of materials to resist stresses imposed by the operation of the machine itself. In military engineering another important element is introduced, and that is that the machine, be it an airplane, battleship, submarine, or tank, has to resist not only the dangers incident to its own operation but the destructive forces loosed against it by the enemy. Under these conditions it is a question of skilful adjustment of the very highest grade in the matter of factors of operation of a device. This may be best illustrated by the consideration of a pursuit plane. In commercial work such as passenger or mail air transportation, the highest degree of stability of plane is sought for. If a plane could be made so foolproof that it could not help flying on an even keel no matter how ignorantly controlled, such a machine would be unhesitatingly adopted by commercial fliers, but not for pursuit purposes. In a pursuit plane it is of the highest importance for the flier to be able to side-slip, nose-dive, fly upside down, roll, and do all such hair-raising stunts. In fact, his very life may depend on his ability to do them, and a plane that would persist in flying on an even keel no matter what was done to it, would be deadly to the combat flier. Here we have an instance of what would be supreme safety in a peaceful-purpose machine turning out to be a deadly danger in a military device.

This distinction between what might be called the engineering factor of safety and the military factor of safety must be thoroughly realized when considering the various devices either suggested at times or applied to submarines. Accidents to submarines may happen in several different ways. Under certain conditions the operation of the storage battery may lead to an evolution of hydrogen which forms an explosive mixture with the air, and this if ignited, as it is fairly bound to be ultimately, is apt to produce quite disastrous results. Such an accident happened in the Brooklyn Navy Yard on one of the submarines in the early part of the World War. Should it happen in the open sea, particularly when a submarine was submerged, the destruction would probably be so great as to make the escape of any one extremely problematic. These kinds of accidents are, however, rare and can be prevented by proper selection of the type of storage batteries and their careful operation.

Generally, emphasis should be laid on the matter of care. The working of a submarine is inherently a very dangerous job. It ranks in this respect in the same category as the handling of high explosives and the most poisonous chemicals. The slightest lack of care in any way is practically certain to lead to disaster. It is surprising, nevertheless, how many accidents on submarines are really due to carelessness of the operators and are therefore entirely preventable. And not only Americans, who are proverbially considered to be reckless, may be guilty of this lack of care but even the supposedly methodical Germans. This is well illustrated by the disaster to the U-3 which sank in the Kiel Harbor because it had submerged with one of the valves open to the water.

Explosions of fuel gases or rather mixtures thereof with air were formerly a possible source of danger when submarines were operated on the surface by gasoline motors. Today with Diesel engines as the practically universal method of drive, this hazard has been practically eliminated.

There is of course always present the possibility of failure of machinery, particularly the electrically driven pumps and air compressors operating the submergence tanks, and also of the failure of controls. In such a case a submarine would have to lie at a certain depth, and it becomes a matter of luck where the accident happens. If the depth is not great and the plight of the submarine is quickly discovered it can be raised, otherwise it is lost.

One of the serious dangers to a submarine lies in the possibility of collision either with another submarine or with a surface vessel. This was the cause of the loss of the S-4 which startled the country recently. Here again it is a matter of luck how it happens. If the collision is of such a character that the men or some of them can escape into one of the watertight compartments and rescue conditions are favorable, there is a chance of their being saved; otherwise there is none, as, for example, in the case of the S-51 sunk by collision with the *City of Rome*.

According to an official statement of the Navy Department the F-4, S-5, S-48, and S-51 are the only relatively modern sub-

marines in our Navy which have gone to the bottom and have been unable to bring themselves to the surface. In the case of the F-4, as the vessel undoubtedly went to the bottom very quickly, no type of rescue apparatus would have been of any value. In the case of the S-5, the bow of the vessel rested on the bottom and the stern projected above the surface. If the S-5 had been fitted with the stern torpedo tubes which are being installed in the latest classes of submarines, the escape of the crew through these tubes would have been a comparatively simple matter. The case of the S-48 parallels that of the S-5, except that the personnel of S-48 succeeded in raising the bow to the surface and effecting their escape through the bow torpedo tubes. The sinking of the S-51 by collision and consequent flooding of the interior of the inner hull resulted in conditions similar to those of the F-4. In the salvage operations on the S-51 the method used in raising the F-4 and the former German submarine U-111, i.e., the "pontoon" system, was employed, with the same signal success.

There have been very many devices proposed for the salvage of submarines. Some of these are too impractical to call for serious consideration—for example, the use of huge magnets to lift the submarine from the bottom. Other devices, however, are in one way or another worthy of notice.

There are certain technical limitations with which the submarine designer has to contend, and those must be most carefully taken into consideration when it comes to the installation of any device whatsoever on a submarine. In the first place, submarines are now built so as to be capable of submersion to increasingly great depths. Where formerly 100 ft. or 150 ft. was considered good, the modern submarine should be capable of freely submerging to a depth of 300 ft., which means roughly a water pressure of 145 lb. to the square inch. This requires a very great increase in the strength of the hull, with a consequent increase in weight. Any addition of weight to the outside of the hull of a submarine requires an increase in size to provide the increased displacement necessary to carry this weight. The result is that when one ton is added to the weight of a submarine in the form of some fixture or attachment, such an increase in size is made necessary as will increase the total weight to the extent of 2.7 tons.

The next great limitation is that of space. A submarine has to carry about three times as much equipment for the power developed as does a surface ship. The propelling plant of the latter is what might be called a single-acting unit, say, steam or Diesel. A submarine carries a Diesel engine which drives it on the surface and also charges the storage batteries. To do this it has to have a powerful generator. The drive under surface is by electric motor from the storage battery. A three-step arrangement therefore becomes necessary, in addition to which the submarine has to carry water tanks, a supply of air, and for its size an inordinate amount of military equipment. It is therefore about as full of machinery as an ordinary watch case, and every square inch of space is utilized to the utmost degree. None of this can be given up to any additional gadget without taking it away from something else.

Safety Weights or Drop Keels

One of the earliest methods of submarine salvage was the use of the so-called "safety weights," which consisted of huge blocks of iron or lead so attached to the bottom of the submarine that they could be released from the inside. The purpose of this was to decrease very rapidly the specific weight of the submarine and permit it to rise to the surface. Such weights were fairly regularly employed up to about the time of the World War, but the recent trend of opinion is against their use. In the first place, it has been found that the working of this device is neither rapid nor reliable enough for practical purposes. In the next place, the additional load reduces the speed of the submarine and its cruising radius to such an extent as to affect very materially the military value of the device. Finally, with the great increase in the size of submarines the weights that could have been used would have had to be inordinately large and, moreover, would have complicated the important problem of balancing when submerged. On the whole, therefore, the present tendency in design is to dispense with their use.

In one instance during the World War the drop keel was accidently knocked off an English submarine by contact with the sea bottom. The vessel was unable to submerge after the accident and ran the danger of being sunk by the enemy, getting back to England by mere fortune. A step in the direction of abandoning this scheme was the adoption of safety tanks. These tanks were filled with water, thus providing an extra weight, and when necessary could be very quickly emptied by introducing very high-pressure air carried for this purpose in special cylinders.

Detachable Chambers

The next device from which great things were expected was the detachable chamber. The idea was to provide in the hull of the submarine small compartments with double doors working something like the Servidor device used in hotels. Double doors were to be provided so that a person could pass into this detachable chamber, close the doors after him, have the chamber detached from the submarine, and float up to the surface. One of the suggestions was to make the entire conning tower act as such a chamber, so that in case of necessity the whole crew of the submarine might save themselves in this way. The problem of designing such a device so that it will withstand when detached the considerable pressures met at substantial depths is not an easy one. Moreover, with the present large submarines carrying a crew of some 85 people, the device would have to be of a very considerable size. The question of placing these detachable chambers is also not an easy one. If they were located inside the hull they would occupy most valuable space, and space is what the designer of a submarine can least spare. If the chambers were located outside the hull, somewhat like warts on a frog's back, they would materially reduce the submerged speed of the vessel.

Diving Suits

It has been suggested many times—but not by submarine designers—that diving suits be provided for the crew, the idea being that in case of accident the crew could don these suits, open doors, and serenely walk out on to the ocean floor. The trouble with this scheme is, first, that in case of an accident, particularly where the hull is ripped open, there is seldom time for the rather elaborate operation of donning a diving suit. Next, not many men employed on a submarine are physically suited for work at substantial depths in an ordinary diving suit. On the other hand, however, in several European navies the so-called "oxylite" masks are carried. These masks have a chemical which is capable of absorbing moisture from the human breath and evolving oxygen in proportion thereto, so that a man can live in an oxylite mask for as long as three-quarters of an hour without breathing any outside air.

The main value of these masks is in case sea water should accidentally penetrate into the storage batteries. Because of the reaction between the sodium and magnesium chloride in sea water and the sulphuric acid in the batteries, such an accident would result in the evolution of chlorine. Should this happen when the submarine was submerged, time would be

needed to bring the vessel to the surface and either ventilate it thoroughly or permit the crew to get outside. For such a purpose masks of the oxylite type are quite valuable, and being comparatively light and small they are not in the way.

THE EXTENSIBLE TUBE

This device has been suggested on numerous occasions, the idea being to provide a tube of a diameter sufficient for a man of ordinary girth to pass through. This tube is supposed to be collapsed under ordinary conditions, somewhat like a traveler's aluminum drinking cup. In case of necessity it is to be extended so as to reach the surface and thus provide a means of egress for men trapped in a submarine. The device has never been adopted in practice by any navy, and the reasons for this are fairly obvious. Such a tube would have to be at least 25 in. in diameter. For a hollow tube to withstand water pressure at a depth of, say, 300 ft. it would have to be made very strong, particularly at the joints, which means that it would have to be quite heavy. It would occupy a lot of room, require quite an elaborate arrangement for extending it, and then would provide egress only to men trapped in the one compartment with which the tube communicated.

SAFETY TANKS

All submarines of the United States Navy are fitted with an automatic device which may be set to operate at a predetermined depth. Several different types of valves have been used, all of which operate on the same principle, i.e., the unbalancing of forces previously in equilibrium by sea pressure due to the depth of submergence. The tripping of such a valve opens the 100-lb. air line to one or more of the main ballast tanks, usually forward of amidships, and allows air to be blown into the tank, forcing the water out through the Kingston valve and thereby bringing the boat to the surface. These valves are not of an automatic repeating type but require to be reset by hand after each operation. Valves of this type have generally proved satisfactory, being capable of arresting the descent of the vessel to within 5 ft. of the intended depth, and criticism mainly has been directed to the capacity of the reducing valve which supplies air from the 100-lb. line. No standard valve has been adopted. Two varieties have been installed on contract-built submarines, both of which are covered by United States patents. A special type of automatic valve has been designed by the Portsmouth Yard and installed on the "S" vessels built by that yard, but has not been thoroughly tested as yet. Automatic control of the diving planes has been suggested and has been considered in a tentative way at various times, but no definite action along these lines has been taken, as it is believed that the complications involved would not be warranted by the advantage gained. The practicability of providing automatic arrangements for controlling the regulating or adjusting pump has been investigated, but in view of the complications involved it is not believed that the arrangement is practicable or would serve any useful purpose.

SIGNALING BUOYS

Many of the European submarines are equipped with signaling buoys which in case of accident can be released by the submarine and will indicate its position. In the German navy, for example, these buoys are equipped with telephones, and at times attempts have been made to equip them at night with flares and in the daytime with smoke or sounding devices. These buoys were formerly quite extensively used in the American Navy, but of late have been discarded. The reason for this appears to be the possibility that in war time the concussion produced by depth bombs might release the buoy and thus indicate the position of the submarine to the enemy. It would seem to be quite feasible to use these buoys in peace time, and either batten them down or cut them off completely in war time.

If properly used and equipped these buoys constitute a valuable auxiliary, in particular, by indicating immediately the location of the submarine and possibly giving information as to the condition of the vessel, the condition of the crew, and the degree of necessity for prompt action. The design of these buoys is, however, as yet in a very crude state, and no facilities are provided for the men in all of the watertight compartments to communicate with the outside world by the telephone apparatus enclosed in the buoy. It may be stated in this connection that the whole subject of submarine safety devices is in an inchoate state, and that even where such devices are used their design is usually quite crude and lacking in that careful working out which characterizes safety devices in civilian engineering.

This matter has been discussed with some of the officers of the Navy Department, who state that signaling buoys are not really necessary any longer. With the present listening devices the submarine can make its presence known quite easily in various ways and can be located without any trouble, provided some one is alive inside who can send out the information. If every one were killed in a accident, the marking buoys would not operate anyway.

WATERTIGHT COMPARTMENTS

In case of partial failure of the hull through collision or otherwise, watertight doors dividing the submarine into several independent compartments may prove to be the means of saving the lives of at least part of the crew. It is in this way, for example, that the lives of the men of the German submarine U-3 were saved, and those on the American S-4 prolonged.

The installation of watertight partitions and doors is a well-known naval device, and its reliability of design has been fully established in the past.

In the American Navy the bulkheads making watertight compartments are considered to be one of the most important provisions for safety on submarines. It is because of their presence that the lives of men on the O-5, S-48, and S-5 were saved. The engineering features involved in the design of the watertight bulkheads are very interesting and are being given the most serious consideration by the Navy. It should be realized in this connection that the big modern submarines are built to operate at depths in excess of 300 ft., which is equivalent to a pressure of about 145 lb. to the square inch. The bulkhead has to be built actually much stronger than even the hull, because while the pressure on the hull is determined by the $2\pi R$ relation, that on the bulkhead, should the water come in, is determined by the πR^2 relation. The modern bulkhead is therefore not a diaphragm structure with a door cut through it as one would imagine offhand, but a system consisting of very strong ribs with inverted dished partitions between them, and altogether represents an extremely strong structure.

EXTERNAL MEANS OF SALVAGE

All the foregoing devices may be classed as internal means of salvage by which the men in a submarine in case of accident can take care of themselves. Assuming, however, that this proves to be impossible, or that the question is not so much the saving of life as the recovery of the sunken vessel, we come to external means. These may be classified into two groups—first, those for the saving of life, and second, those for the salvage of equipment. In war time, under certain conditions, the order of importance is reversed, the equipment being considered more valuable than the few lives which it may contain.

AIR SUPPLY TO THE SUBMARINE

Only recently has this problem been thoroughly studied. There are two views as to how it should be done. One way is to supply air to the general air system, which includes the submergence tanks. The piping is so arranged that under ordinary conditions air pumped from outside will be delivered to all compartments. This may not happen, however, if the submarine has been seriously damaged, as, for example, was the case with the S-4. The other way is to provide proper valve connections so that air can be admitted to individual compartments even when the general air system is injured. The former system has been adopted on American submarines. As a makeshift, air can be supplied to some compartments, as, for example, through the listening tubes, provided the proper valves are opened from the inside, and provided proper connections are either available or have been made for attaching the air hose. It does not appear clear why both systems should be used simultaneously, and it would appear perfectly feasible to change somewhat the piping arrangements, possibly by providing two-way valves, so that the system could be used either as a single system or for supplying individual compartments.

LIFTING MEANS

In the event that the injury to the submarine is of such a character that there is no way for it to rise to the surface of itself, even with the main tanks emptied of water, the thing to do is to raise it by outside means. There are only two ways available: one is to attach to the submarine additional tanks, force the water out of them, and thus float the vessel; the other is to attach chains or wire ropes directly to the submarine and hoist it by brute force. In either event the operation falls into two stages: (1) attaching lifting pontoons or hoisting chains to the submarine; and (2) putting through the hoisting operation itself. When plenty of time is available the operation is comparatively simple, provided of course that the submarine lies at a depth at which diving operations can be carried out without extreme difficulty. Where sufficient time is not available, those who are going to carry out the raising operation will sincerely appreciate any provision for doing the work as quickly as possible. It may be mentioned in this connection that time may not be available for two reasons. In the first place, men yet alive may be caught in the sunken vessel and the highest possible speed of operation may be needed to preserve their lives. In the second place, weather conditions may be such as to afford only a limited time in which to do the job. A combination of these two conditions was present, for example, in the initial salvage operation of the S-4.

MEANS OF ATTACHING CHAINS OR PONTOONS TO A SUBMARINE

Any engineer who has had experience with crane operation or derrick work in construction knows the great difference between raising a heavy piece so designed that it can be conveniently held by the crane hooks or chains, and doing the same job with perhaps a much lighter piece of such a shape that one has to use special ingenuity to hold it and is then perhaps not quite certain of being able to do so. While every designer of submarines knows that because of its very character of operation it is apt to get into trouble, out of which it will have to be pulled by raising, still the provisions for carrying out this operation are anything but ample. The most obvious way to assist in the raising operaton is to do with the submarine what is, for example, done with a ladle or ingot mold in a steel mill, i.e., provide it with either bosses or eyes to which hooks or chain loops can be engaged. In fact, the Navy has been blamed by some congressmen for not having done so in the case of the S-4. However, this question of hooks or bosses is more involved than appears on the surface. The early submarines were quite frequently provided with eyes riveted on the hull. Those vessels however, were comparatively small and the load on each eye was therefore quite light. With large modern submarines a rather different situation presents itself.

It should be remembered in this connection that the stress is not applied evenly to the eyes in lifting a submarine. A crane operator lifting a foundry ladle can more or less control the stress on the crane hook by pulling it up slower or faster. He is, however, operating from a perfectly fixed base, the crane bridge. The salvage vessels, on the other hand, when raising a sunken ship have no such fixed base, but on the contrary are supported by that most restless element, the ocean, with the result that the stress is either half eased off or suddenly applied with a powerful jerk. The strength of the hook or eye on a submarine is no greater than the strength of the rivets or the weld that holds it to the hull, or the strength of the hull itself. A brief calculation will show that if it were attempted to raise a submarine of the size of the S-4 by a few hooks or eyes welded or riveted on to it, the chances are that the hull would be ripped apart or the hooks torn away.

Of course, the reply to this will be, why have a few hooks and not a multiplicity of them? Here again the trouble lies with the lack of a fixed base. If we were to hoist a load from a crane bridge, it would be a comparatively easy proposition to provide, if necessary (and it is seldom necessary), a multiplicity of chains and arrange them in such a manner that the load would be easily distributed among all the chains. If, however, the same thing were attempted in marine salvage operations without some very special equipment, the chances are that the load would alternately vary and be carried at all times by some two or four sets of eyes, at least to the extent of 75 per cent, so that the multiplicity of these eyes would not materially help in relieving the stresses on the hull.

The French submarine designer Laubeuf proposed, however, a modification of this device which appears to be of sufficient importance to deserve serious consideration. What Laubeuf suggested is to attach wide bands of metal to the submarine by riveting or welding and to have the hooks or eyes for the accommodation of the lifting chains made a part of these bands. In this way the hoisting stress would be distributed over a comparatively wide area of the hull, and with proper design and distribution of these bands it would appear possible to give these hooks or eyes such proportions and such a distribution as would assist materially in accelerating the raising operations.

Since Laubeuf's time a new development has taken place which may help in this connection. All that Laubeuf had at his disposal were carbon-steel bands with a tensile strength of some 100,000 lb. Today it would be possible to make these bands in the form of chrome-nickel steel forgings with a tensile strength considerably in excess of 200,000 lb. and a permissible emergency loading of some 175,000 lb. per sq. in. Under these conditions such bands with the concomitant hooks or eyes would appear to be well deserving of serious consideration.

It should be borne in mind that the provision of bands will require in the first place possible changes in the design of the longitudinal frame members of the submarine, with the idea of giving them additional stiffness. This is a more difficult problem than a layman or engineer who has not had anything to do with submarine design realizes. The other point to which very serious consideration must be given is such streamlining of these bands as will not materially reduce the submarine speed, particularly its surface speed, the underwater speed being too low to be materially affected by the presence of the bands.

ATTACHING CHAINS TO SUBMARINES

Obviously, before a submarine can be lifted, chains have to be passed properly around it. It may be somewhat surprising to an engineer to learn that no provision for doing this quickly and conveniently is made on any of the submarines of any country. The submarine may be lying in the most inconvenient position, on a rocky bottom or—which is equally bad if not worse—partly sunken in mud as is the case with the S-4. When this happens tunnels have to be laboriously blown under the submarine hull to pass the chains or hoisting ropes. This means increasingly hard and dangerous work on the part of the divers, possible interruptions by weather, with destruction of what has been already done on the bottom, and furthermore no certainty that the chains will be placed where they should be. To an engineer it would appear that a very simple provision could be made to take care of this situation. This could take the form of welding on to the submarine hull a few thin channel-shaped pieces so

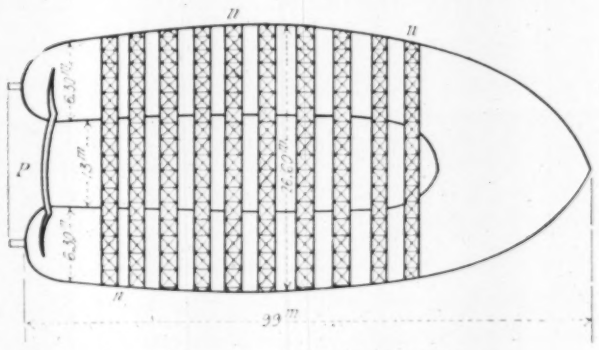


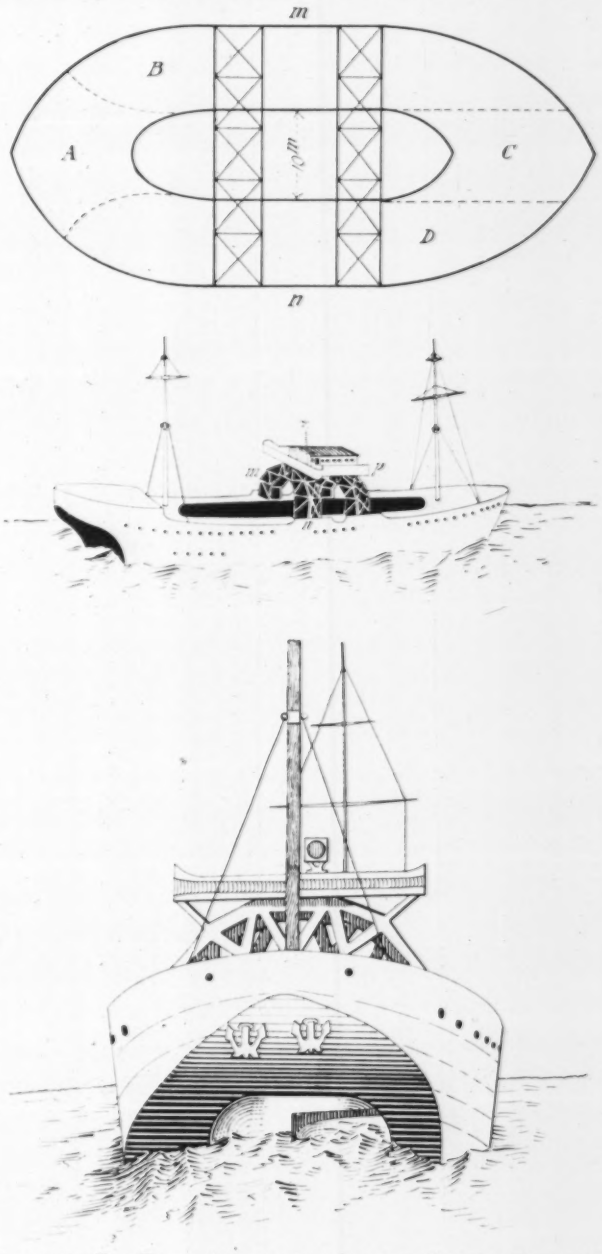
FIG. 1 FRENCH SUBMARINE SALVAGE VESSEL

arranged that they could be opened in places and serve as guides for the hoisting chains. It would be a simple matter to locate in these channels a slender wire rope with proper provision for attaching the chain at one end and passing it around the submarine by pulling on the rope from the other side. The operation in principle would not differ from the way in which heavy cables are passed underground by the telephone companies. Proper thought should be given to making these channels of such a shape as not to reduce the surface speed of the submarine, but otherwise the device is extremely simple. There is one objection to it, however, and that is that these guide channels being made of fairly thin metal, would be apt to get bent or twisted. Should this happen the submarine would be no worse off than it would be without them, and there is really no reason why they could not be made strong enough to withstand ordinary bumping.

SUBMARINE SALVAGE VESSELS

The next great question is that of the apparatus for hoisting the foundered submarine. The mass to be raised in this case may amount to as much as 75 to 80 per cent of the surface displacement of the submarine. Taking the latter at 1200 tons, which is fairly close to present practice, the weight to be raised would have to be estimated at about 960 tons. The first question, therefore, is to provide a sufficient number of chains in order not to twist the submarine all out of shape in raising it, or perhaps break it in two. On the small prewar type of German submarine three fixed points were provided, distributed longitudinally. On French submarines lifting eyes were provided in pairs, one eye on each side, from six to seven pairs being used. However, this multiplication of points of suspension makes it necessary to employ special devices to equalize the loads imposed on the different chains. Load-limiting brakes have to be used in order to limit the rupture of chains by overloads and also to prevent some of the chains from carrying the whole weight and others none of it.

The speed used in hoisting in the European navies is on an average from 0.4 to 0.8 in. per sec. Notwithstanding such low velocities the total power at the drum is quite considerable because the efficiency of the transmission is probably under 40



FIGS. 2–4 THE GERMAN SUBMARINE SALVAGE VESSEL "VULKAN"

per cent. Taking a speed of 0.4 in. per sec., the effective work in hoisting a submarine of, say, 1000 tons, is 66,666 ft-lb. per sec. or close to 120 hp. Assuming an efficiency of 40 per cent, it would appear that the power of the hoisting engine must be at least 300 hp., and it is usually a good deal more than that in catamaran-type hoists provided with propeller screws on both sides. This arrangement is used on the German *Vulkan* and the Brazilian *Ceara* submarine salvage vessels.

There are two types of arrangements employed on submarine salvage vessels. In one type the hoisting chains are passed through vertical holes in the body of the ship itself; in the other type, they are passed over sheaves usually located in the stern of the vessel. The German salvage vessels *Nordsee* and *Ostsee* embodied the former type of construction, while the *Oberelbe* and *Unterelbe* had sheaves located on the stern and carried between the arms of a cantilever support.

Coming now to the types of vessels, the French have developed what is known as a "kangaroo" ship. In this, part of the bow opens up, permitting a submarine to enter. The doors are then closed and the water expelled, leaving the submarine high and dry. The original purpose of the design was to transport submarines built in France overseas to places where they would be put into service.

Further details concerning an older type of the French submarine vessel are given in Fig. 1. It must be realized, of course, in this connection that everything concerning the submarine services of the various navies is in the "hush-hush" class. Publication of data of recent developments is not encouraged. From information available, however, it does not appear that the most recent vessels are in any way radically different from the one described here. This particular vessel was built in 1911 by the Loire Shipbuilding Co. and has a displacement of 2430 tons. It is equipped with electric motors rated at 170 kw. As shown in Fig. 1 it has one bow, but the stern is divided in two, with an open space between the two sections 13 m. (42.6 ft.) wide. The two parts are powerfully braced together by the bridge structure *P*, but each part is equipped with a rudder of its own to facilitate maneuvering. The main dimensions are: length, 99 m. (324.7 ft.); width of each of the two sections, 6.30 m. (20.6 ft.); width between the sections, 13 m. (42.6 ft.). The vessel is capable of lifting up to 1000 tons.

The structure supporting the suspended load is formed of ten steel frames interconnected so as to form a single powerful bridge. The chains are 66 mm. (2.6 in.) in diameter.

A very interesting type of submarine salvage vessel is the German *Vulkan*, Figs. 2, 3, and 4. This vessel is 70 m. (229 ft.) long and 16.75 m. (55.25 ft.) beam. Its center part consists of two hulls with parallel axes and an intervening distance of 10 m. (32.8 ft.). These hulls are jointed together both at the bow and at the stern, leaving an elongated free space in which the operation of raising the submarine is performed. For this latter purpose is provided a huge bridge member *p*, Fig. 3, supported on metal frames *m* and *n*, Fig. 2. The great strength of this structure is shown by the fact that it is capable of supporting a load of 600 tons. A submarine may be actually lifted from the water and supported inside the hull of the ship. Facilities are provided for minor repairs.

THE LAURENTI SALVAGE VESSEL

One of the most interesting designs for submarine salvage work is shown in Fig. 5, for which credit is due to the Italian engineer Laurenti. The purpose of this vessel is really twofold, as in addition to submarine salvage work it is also designed for carrying out certain acceptance tests on submarines. The most important of these is the test of the vessel for its ability to stand pressure when submerged to a certain depth. The conventional method of carrying out this test, which consists of letting the submarine submerge to a given depth, is somewhat like the famous method of determining whether certain mushrooms are of the right kind. Eat them, and if you die you know they were toadstools. It does not help the crew of the submarine very much to find out at a depth of, say, 100 ft. that their submarine hull is not strong enough.

The Laurenti design comprises a long and extremely strongly built steel tube capable of resisting the designed high pressures. It is supported by four U-shaped caissons *B*, located one at each end and two at even intervals between. These caissons have inside of them ballast tanks so arranged that water can be admitted into the pressure tube *A* when lowered to the desired extent, which is so low that the submarine can float into it. The water is next expelled from the ballast tanks of the caissons *B*, which makes the pontoon rise and lift the submarine with it. As the water is expelled the submarine gradually comes to rest on powerfully-shored-up wedge blocks. When this is done the hood *E* is set in place, enclosing the control turret, while watertight doors at the bottom of the pressure tube are closed. The hood *E* is equipped with rubber rings, the purpose of which is to make the joints perfectly watertight.

The next step is to pump water into the space between the pressure tube *A*, including hood *E* and the submarine *D* contained therein, it being of course assumed that the submarine has all the valves closed and is generally in proper state for submersion. A steam-driven pump of adequate power is used and water is

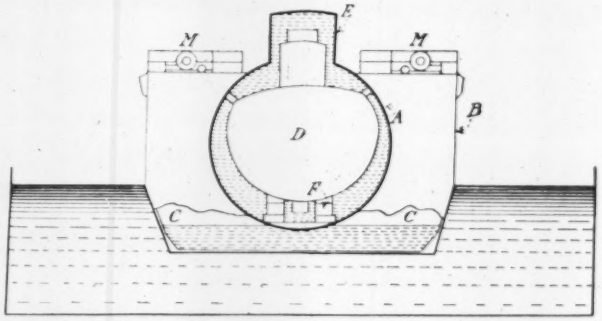


FIG. 5 LAURENTI'S SUBMARINE SALVAGE VESSEL

applied at such a pressure as may be designed for test purpose or otherwise. The advantage of this method of testing is that even should the submarine hull fail to support the required pressure, neither would the submarine be lost nor the personnel endangered. It should be remembered that in such a test the engineering personnel has to be inside of the submarine in order to make the necessary observations and also test the working of the various devices while in the state of submersion. In this case the engineers and officers are at all times in telephonic communication with the pontoon personnel and the test may be stopped and the water pressure released very rapidly, if desired.

The Laurenti pontoon may be also used for the salvage of submerged submarines. To do this the caissons are lowered to the desired depth with strong chains and hooks which may be attached to rings or bosses on the submarine. When such an attachment has been effected the ballast tanks on the pontoons are emptied, which produces a very powerful upward drag. The device may of course also serve as a drydock in which case the submarine is taken in the usual manner into tube *A*, which is then closed at the ends, and water completely expelled, leaving the submarine dry and accessible for all repair work.

The Brazilian Navy has had constructed at the Fiat-San Giorgio Works, from the designs of Laurenti, a mother ship for submarines. This vessel has the following dimensions:

	Meters	Feet
Length between perpendiculars	100	328
Maximum beam	15.50	50.8
Height	8.2	26.9
Full-load immersion	4.2	13.8
Displacement, tons	4200	

This vessel is designed to carry accommodations for the

personnel and officers of a squadron of six submarines each of a displacement of 250 tons or thereabout, or three submarines each with a displacement of from 250 to 400 tons. The vessel is to carry sufficient supplies of fuel to accommodate these submarines and is equipped with facilities for supplying them with sets of fully charged storage batteries in exchange for those on the submarines. It also has facilities for recharging the submarine reserve tanks, thus saving the submarine machinery from too frequent use. The mother vessel carries all the service and reserve torpedoes of the squadron, as well as such other military material as may be required. It also has a well-equipped shop for taking care of usual repairs. As the main motors for operating the auxiliaries are of the Diesel type and the electric and compressed-air machinery of a type similar to that used on the submarines, the mother ship can also serve as a school for submarine personnel.

In addition to the equipment for submarine salvage it has also two diver outfits. It has one tube for carrying a submarine of the type described above and of the following dimensions:

	Meters	Feet
Length of the cylinder body	64	210
Maximum useful length	55	180
Average diameter of cylinder at the entrance orifice	7.56	23.80
Net inside diameter of cylinder	7.07	23.18

For raising the submarine the vessel is equipped with a crane for handling up to 400 tons, while for its own defense against enemy destroyers it carries eight 100-mm. (4-in.) guns and four 57-mm. (2.25-in.) guns.

CONCLUSIONS

When all is said and done, one thing remains unfortunately true, and that is that a submarine is inherently a dangerous sort of vessel to operate. There are ways to make it somewhat less dangerous to its crew, but thus far no really safe submarine is in sight. With this fact fully recognized, there is no reason, however, why submarines should not be made much safer to operate than they are now. With proper arrangements certain classes of accidents can be largely though not entirely prevented, while certain other classes can be made less deadly. The proper way to go about it is to devote real and sincere attention to the problem. Many of the most hazardous operations in industry have been made safe, or comparatively so, by proper attention to the element of danger.

In the first place, it should be clearly realized that submarine operation in peace time is different from that in war time, and that certain risks which must of necessity be taken when operating on a war footing are unnecessary in peace-time operation. Safety codes should therefore be prepared for submarines as well as for all other war vessels operating in the areas where submarine exercises are being undertaken. To such extent as is necessary commercial vessels should either be kept out of such areas entirely, or else they should be properly instructed as, for example, by radio to be on the lookout for submarines when operating in exercise areas of the latter. Such a comparatively simple and perfectly feasible program would have prevented the two disasters which have occurred within the last couple of years, namely, those of the S-51 and S-4.

In peace time no submarine except as part of a military maneuver should be permitted to operate without some device to indicate its rising to the surface at least 3 min. before the actual rise occurs. It is immaterial whether the device acts by sound or visually. If the latter is the case the device ought to be so arranged as to provide a signal both in the daytime and at night. There are a number of such devices that can be used. The Chemical Warfare Service would be ready to design a number of them combining black smoke for use in daytime and a powerful flame for use at night, the flame part being of such a character that it would not be affected by water spray. The size of such a device is very small. The signaling bomb for a 3-min. operation need not be more than, say, a cylinder 9 in. long by 4 in. in diameter, and it can be projected from the submarine by a device resembling a miniature torpedo tube. The details of such a device are so simple that any navy mechanician could build it. Several such are actually known and some have been used by the American Navy in the past.

Simple means should be provided by which a submarine which is unable to rise to the surface for any reason whatsoever could indicate unmistakably its position. These means should be so installed that they could be operated from any of the watertight compartments. They may take the form of a small buoy with or without a telephone connection. Where for some reason this is not feasible, a cork or balsa float may be substituted.

Special connections for the supply of air should be provided in every compartment of a submarine, and corresponding connections should be available on every vessel owned by the United States Government or rescue companies (more will be said about these later) that may be called upon to take part in submarine salvage work.

Above all it is vitally important that submarine salvage work should be systematized. So long as it is known that a submarine is inherently a device dangerous to its operating crew and so long as submarines have to be used for national defense, it is rather unreasonable to consider a submarine disaster as an emergency. It is nothing of the kind. It is an inherent part of the hazard of operating a submarine, and suitable provision should be made to meet its occurrence. In large mills engineers do not consider accidents to workmen as emergencies. They know that no matter how careful the operators may be, things will happen. People will be cut, will have their fingers caught in gears, will be hurt by flying pieces of metal or by falling weights. In properly conducted mills a careful program is worked out for rendering first aid and for taking care of more serious cases. First-aid cabinets are provided and foremen are carefully instructed on how to behave in case of more serious accidents which cannot be handled by facilities available in the shop. There is no reason whatsoever why the United States Navy should not have a similar plan.

There is a story, whether authentic or not is immaterial, to the effect that when the Franco-Prussian war of 1870 was declared, Moltke, then chief of the German General Staff, was awakened in the middle of the night and told of the declaration of war. "Plan No. 4," he muttered, turned over, and went back to sleep.

There is no reason why in case of a submarine disaster a similar course should not be followed. Instead of having lieutenant-commanders, commanders, admirals, and such like running around and devising ways and means on a Saturday afternoon, all that should be necessary would be to take a certain envelope marked, for example, for the Portsmouth, New Hampshire, Area, as "Plan No. 4," and send out by radio or wire these three words; then we should know exactly beforehand what would happen.

Obviously, the Navy alone cannot and should not be called upon to provide complete facilities for submarine salvage all along the thousands of miles of the American coast from Maine to Panama on the Atlantic, and Panama to British Columbia on the Pacific. All along these coasts there are many commercial companies which are more or less well equipped to do this kind of work and would be proud to take part in it at only the most reasonable compensation. It would be a comparatively simple

matter for the Navy to make agreements with all such companies by which they would specify the equipment available for salvage operations in their respective districts and keep the Navy posted as to the movement of such equipment. Some one at a desk in Washington ought to be able to tell at a glance what derricks, divers, etc. are available at 4 o'clock on a Thursday afternoon outside of San Diego Harbor, and the information should be sufficiently precise to make it absolutely certain that it is good for Thursday of this week and not two weeks ago. With such information it would be a comparatively simple matter to assemble, practically at a moment's notice, all salvage equipment required, and it would not be necessary for the Navy to try to locate the men responsible for the equipment and arrange for terms on which such equipment could be used. A steel mill knows exactly to what hospital it can send a man injured in its plant. A railroad, all along its right of way, knows the hospitalization and relief facilities. The Red Cross has a skeleton organization of that kind, and there is no reason why with a comparatively little trouble the Navy should not.

In each district and at each submarine base there should be kept special codes for work on each submarine operated in that particular district. Submarines differ considerably in types and sizes. Those which will be built from now on will probably be more amply equipped with safety devices than those of the older makes. It may be also that the new safety devices will be operated differently from the old ones. New fittings will probably be installed and their location may not be familiar to the divers, etc. There is no reason why, knowing that men only in a certain compartment are alive, air should be supplied in a way in which it cannot reach that particular compartment. A simple blueprint showing how to attach air hose so as to help men in a given compartment will easily obviate such an occurrence. In each district, therefore, complete information in a form that he who runs may read should be available. The signaling facilities of each particular submarine should be indicated, the location and size of air connection should be shown, and the corresponding connections should be specified. A supply of all connecting pieces, chains, hooks, etc. should be kept in charge of the same office that keeps the information as to the method of procedure of salvage of each submarine.

The Navy and Army Air Services and commercial aeronautical companies, including the Air Mail, should be given an opportunity to thoroughly familiarize themselves with submarine salvage programs and show ways in which they may be helpful. It may happen that some gadget vitally necessary for submarine salvage work is missing. It should not be necessary to scurry around and search for an airplane that could rush it to the proper destination. The Navy office in the particular district in which the need occurred should be able to turn to its files and find the telephone number of the office of the Air Service or commercial aeronautical company that should at that particular hour have a machine available to carry the part required to its destination.

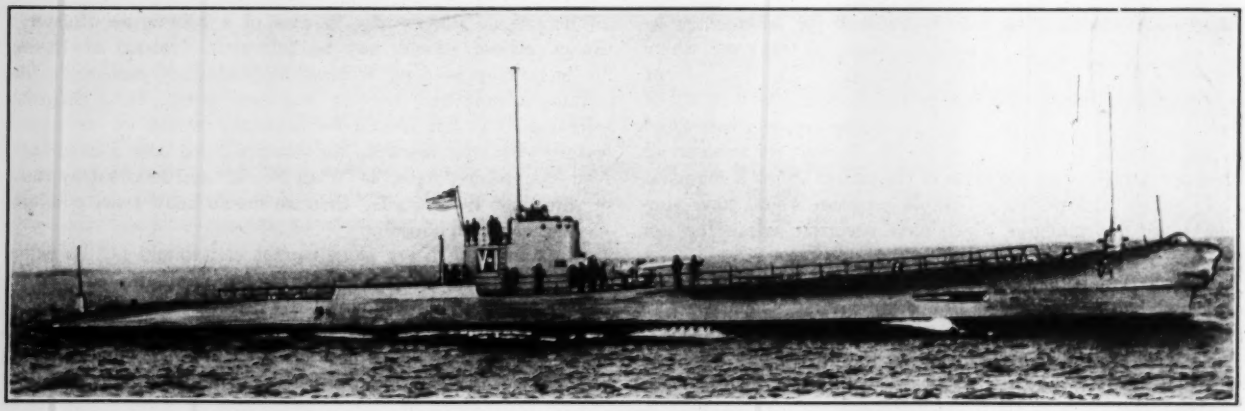
When a submarine is sent for a prolonged cruise out of its regular range of operation in peace time, all districts within the range of which it will have to pass should be notified, and be on the lookout and prepared to handle anything that may happen, not in the spirit of emergency, but as a part of their regular day's work.

There is one reaction that may be expected to the above program. What has been outlined above will require going to a considerable amount of trouble and to no little expense. Submarine accidents are comparatively few and far between, and the question may be raised whether it is worth while to go to such a lot of trouble for such an infrequent emergency.

Some officers, including the commander of a submarine, appear to feel that the problem of submarine safety should be considered from two points of view. In the first place, the utmost attention should be paid to improving the design of the submarine in the way of increasing its mechanical strength, making the operation of the submarine more reliable, and particularly in increasing its military efficiency. Their feeling is that the real question of safety will arise when the margin becomes vanishingly small, and that is under war conditions, and it is of the utmost importance for the men to see that this margin of safety under war conditions does not vanish entirely.

Because of this a whole list of improvements have been made, which, while not classified specifically as safety devices, nevertheless strongly contribute to safety.

As to outside salvage means, the feeling seems to be that while all should be done that can be reasonably done with approximately the present amount of attention and explanation, it would not be wise to undertake an elaborate and expensive program of safety and salvage provision for submarines. It appears to be felt that the number of accidents has not been very large considering the extensive use of submarines being made in peace time. A statement has been made, for example, that in one Atlantic area only, subsurface work with submarines is being done approximately one day in every two, year in and year out. According to the proponents of this view, such money as can be secured from Congress ought to be used for general Navy purposes and will in this way ultimately contribute to the increase of safety of submarines. This is a view which deserves very serious consideration as it comes from men who are most closely connected with the design and operation of this branch of Navy equipment. This is not the place to discuss it.



THE V-I, THE LARGEST SUBMARINE IN THE UNITED STATES NAVY

Procedure Control in Pressure-Vessel Welding

By H. E. ROCKEFELLER,[1] NEW YORK, N. Y.

THE oxyacetylene welding of large pressure vessels during the past year has gained considerable impetus and is creating a rather widespread interest both among purchasers and manufacturers of this equipment. One large company has standardized on this process of fabrication for practically their entire pressure-vessel requirements, and, being chemical manufacturers, their needs naturally encompass a wide latitude of application. During the past year they alone have purchased over sixty oxyacetylene-welded pressure vessels ranging in diameter from 4 to 7 ft. and in operating pressure from 125 to 400 lb. per sq. in.

Among the recent applications the construction of six vessels, 6 ft. in diameter by 26 ft. in length and designed for 300 lb. operating pressure, presents probably the most representative example of the present status of pressure-vessel welding.

The practices established to regulate and advance the application of oxyacetylene welding are known as "procedure control" standards. This term has come to mean to welding what standardization and scientific management mean to industry in general. It implies an analysis of the factors involved in any welding application and the consequent intelligent pursuit of certain known and desired results. These factors for pressure-vessel welding include:

a Correctly designing the vessel and welded joints
b Selecting material of good welding quality
c Determining the ability and knowledge of the welding operators
d Properly preparing the material for welding
e Applying approved welding technique
f Satisfactorily testing the completed vessel.

Design of Vessel and Welded Joints

Consider a typical vessel designed for an operating pressure of 300 lb. per sq. in. on a 6-ft. diameter, with a shell thickness of $1^1/_4$ in., based on a design fiber stress of 9000 lb. per sq. in. This design fiber stress, it might be mentioned, was adopted for pressure-vessel construction in July, 1926, and represents a gradual increase based upon experience and investigation since 1923 when 7000 lb. per sq. in. was the limiting fiber stress in design. The heads are of a design which gives a total depth of dish equal to one-quarter the diameter of the tank. The two sections of spheres composing the knuckle and crown radii were selected so as to give an approach to a semi-ellipsoid whose major axis is twice the minor axis. The manhole reinforcing ring, it will be noted, is also of special design and is so dimensioned as to reduce to normal the stresses about the manhole opening. A more detailed discussion of these designs for use on welded pressure vessels will be given in later paragraphs. The outlets and sump were designed so as to permit of satisfactory welding of the lighter outlet wall to the heavy shell wall.

The design of the welded joints for all seams is of the double-vee butt type, the included angle of vee being specified between 90 deg. and 100 deg., with a reinforcement on each side of the weld of not less than $^3/_{16}$ in. The ultimate strength of this type of joint when properly executed considerably exceeds the requirement of the factor of safety of 5 based on the comparatively low design fiber stress used. It will also be noted that the shell is made up in three long plates with no girth seams between the heads. This design was employed because of the greater facility in welding longitudinal seams.

Selection of Material

In order to insure the quality of the material used, firebox steel with a maximum carbon content of 0.20 per cent and a minimum tensile strength of 50,000 lb. per sq. in. was specified. The specifications also call for the use of $^5/_{16}$-in. Oxweld No. 1 high-test welding rod. It might be said in connection with the material secured for this job that the maximum carbon content of all the plates as indicated in the mill-test reports was 0.19 per cent and the minimum tensile strength 52,560 lb. per sq. in.

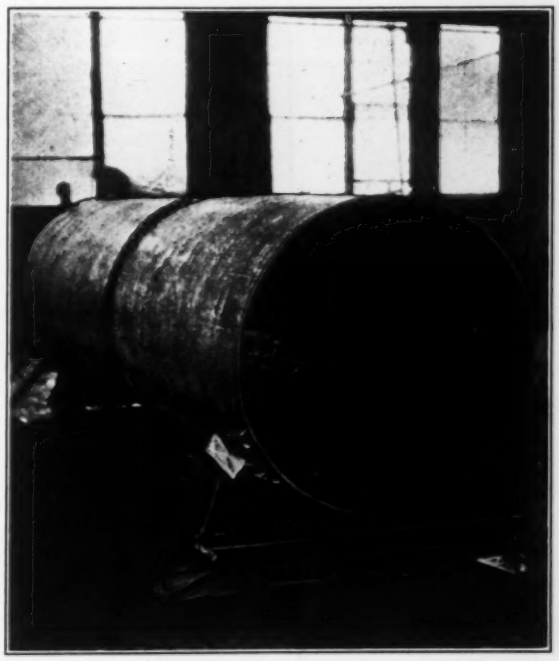


Fig. 1 Showing Method of Lining up Longitudinal Seams

In order to provide the proper facilities for welding the $1^1/_4$-in. plate, an Oxweld No. 30 head was used, which has a capacity of 150 cu. ft. per hr. of oxygen and acetylene.

Check of the Welders

As a check on their ability to meet the welding specifications, each operator was required to pass a qualification test. The test included the welding together of two sections of plate, each 9 in. × 12 in. × $1^1/_4$ in. in thickness, the plate being double-beveled along the 12-in. side. Six specimens were cut from each of the test plates and the reinforcement removed from half the specimens. The requirement for passing this qualification test was that none of the specimens should show an

[1] The Linde Air Products Company.

Presented at the convention of the International Acetylene Association, Chicago, Ill., November 16 to 18, 1927.

ultimate strength of less than 50,000 lb. per sq. in. of plate section.

RESULTS OF TENSILE TESTS ON QUALIFICATION-TEST SPECIMENS

In most instances only the specimens ground flush with the plate were tested. All welders submitting test specimens with the exception of one were accepted on the first qualification test. This welder, after further experience, submitted another test coupon which showed a minimum weld strength of 56,100 lb. per sq. in.

These figures are also interesting in that they show the usual large percentage of fractures to have taken place in the plate, even where the weld reinforcement was ground off.

FIG. 2 HEAD READY FOR WELDING TO THE SHELL

FIG. 3 WELDING THE MANHOLE REINFORCING RING

PREPARATION OF MATERIAL FOR WELDING

The steps taken in the fabrication of the plates preparatory to welding are noteworthy because of their simplicity. In laying out the plates it was necessary only to establish guide lines for beveling and resquaring. These operations, furthermore, were accomplished on a single set-up of the plate planer. The edges of the plate were next set to the proper curvature for a distance of 12 in. to insure complete concentricity of the shell.

Following the rolling operation, the three plates comprising the shell were fastened by means of wedge clamps and then moved to the portion of the shop where the welding was to be done.

Prior to welding each of the longitudinal seams, one end was tack welded and the other separated the required distance to provide for contraction. For tacking, a spacing of $^1/_8$ in. was used and a tack weld made about $1^1/_2$ in. in length. When necessary a turnbuckle was employed to secure this desired spacing. The spacing of the seam for welding was secured by inserting a wedge at the open end and spreading the plate edges about 5 in. at this point. This provided an allowance for contraction during welding of approximately $^1/_4$ in. to the foot.

In order to minimize the tendency of the plate to force outward on the ends of the seam, a heavy plate clamp was employed. This plate clamp was inserted at both ends of the seam on the under side when welding the outer vee and on the outside when welding the inner vee of each of the longitudinal seams.

WELDING LONGITUDINAL SEAMS

In joining the longitudinal seams, the welding of the outer vee was accomplished first. One welder was responsible for each seam, being given assistance, when necessary, by a helper who adjusted the wedges and clamps so that the spacing could be controlled properly and so that the distance between the abutting edges at the point where the welding was being done was maintained at the proper distance. By doing this a spacing of $^5/_{16}$ in. between the plate edges, a foot ahead of the point of welding and about $^1/_{16}$ in. at the point of welding, was maintained for the entire length of the seam. This provided a sufficient opening to secure thorough penetration easily, without slowing up the welding operation as occurs when too wide a separation exists at the bottom of the vee.

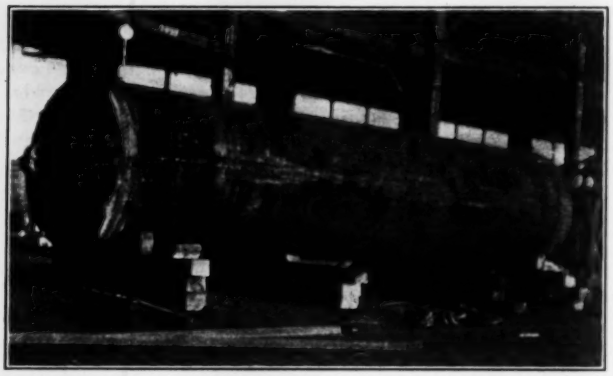


FIG. 4 THE COMPLETED VESSEL UNDER TEST

When welding had to be stopped because of the necessity of having the welder take a rest or because of shutting-down time, the wedge used to maintain the spacing was thoroughly secured and the plate clamps and jack also tightened up so that the alignment could be maintained. Before starting up again the weld was reheated for a distance of about 12 in. to open up the seam and relieve the pressure which had been imposed on the wedge by the cooling of the seam when the welding was stopped.

After completing the seam from the outside the inner vee was chipped out to remove the oxide and excess metal which had penetrated to the inside of the seam without being thoroughly fused with the base metal. In welding the inner vee, preheating was employed to provide the necessary additional heat required after one side of the seam had been welded. Furthermore, this preheating medium, which consisted of a steel-plate box about 24 in. long and 6 in. wide, fed with coke and air, had a tendency to anneal the seam as the welding progressed.

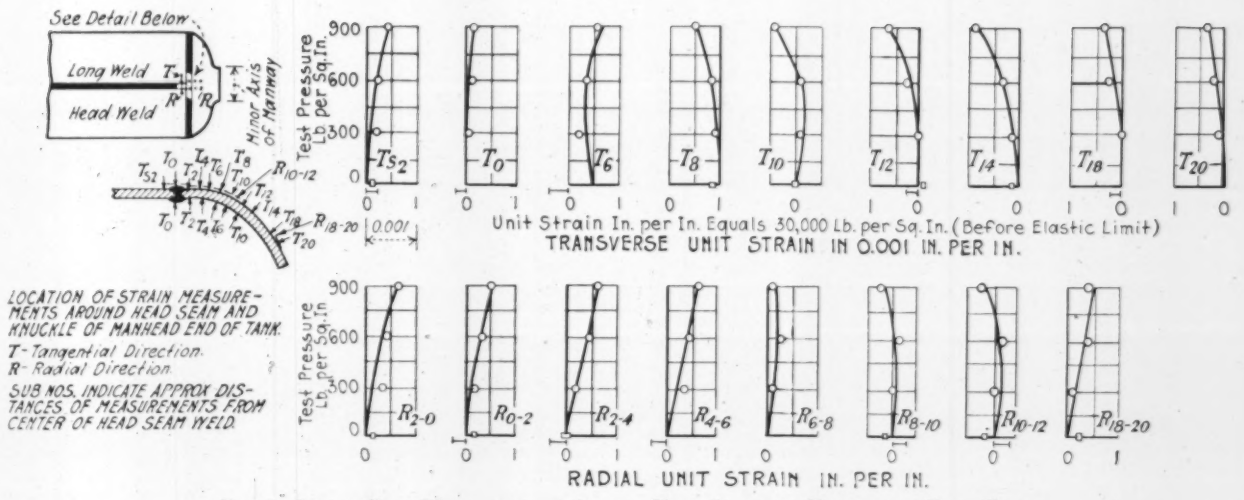

See Detail Below
Long Weld
Head Weld
Minor Axis of Manway
LOCATION OF STRAIN MEASUREMENTS AROUND HEAD SEAM AND KNUCKLE OF MANHEAD END OF TANK.
T-Tangential Direction.
R-Radial Direction.
SUB NOS. INDICATE APPROX DISTANCES OF MEASUREMENTS FROM CENTER OF HEAD SEAM WELD.
Test Pressure Lb. per Sq. In.
900
600
300
0
0.001
Unit Strain In. per In. Equals 30,000 Lb. per Sq. In. (Before Elastic Limit)
TRANSVERSE UNIT STRAIN IN 0.001 IN. PER IN.
RADIAL UNIT STRAIN IN. PER IN.

FIG. 5 STRAIN-GAGE MEASUREMENTS AROUND HEAD SEAM AND KNUCKLE OF TANK END

WELDING OF MANHOLE REINFORCING RING TO MANHEAD

The reinforcing ring was first set up and leveled so that the beveled edges of the ring and manhead coincided about the entire seam, an equal spacing of about $^1/_4$ in. being provided. Four tack welds were next made at equidistant points on the seam, each two being made simultaneously at points 180 deg. apart. These tack welds were about 4 in. in length and without reinforcement. Upon the completion of the tack welding, a preheating fire was started under the head which was so designed as to provide the greatest amount of heat at the seam and in the heavy section of the manhole reinforcing ring. A natural draft was provided, entering through openings around the bottom of the head and leaving through the elliptical opening in the reinforcing ring. Charcoal was used as a preheating medium, being distributed within the furnace from the elliptical opening. Preheating was carried on until the manhole reinforcing ring and head in the vicinity of the weld had been brought up to a dull red. Welding was then started by two welders working simultaneously 180 deg. apart and using long-handled blowpipes. A flat weld was employed on this seam as it was found to give a more satisfactory design.

After completing the weld from one side, the head was allowed to cool slowly to room temperature. The excess metal was then chipped from the inner vee and the head again preheated and welded as previously described. In order to eliminate any locked-up stresses, the head was completely annealed following the completion of the welding.

LINING UP AND TACKING HEAD SEAMS

The lining up of the head seam was accomplished by the use of the same wedge clamps previously mentioned in connection with the lining up of the longitudinal seams. These clamps were inserted at equidistant points about 12 in. along the entire seam. A spacing of about $^1/_2$ in. between the abutting plate edges was employed.

When the seam had been completely aligned, four tack welds were made, two welders working at points 180 deg. apart, one on the top welding on the outer vee and the other within the shell welding the inner vee. The shell was then turned through 90 deg. and the other two tack welds made. Each tack weld was about 4 in. in length and without reinforcement.

WELDING THE HEAD SEAM

The actual welding of the head seam was accomplished in much the same manner as were the longitudinal seams. Instead of the welder moving along the seam as the welding progressed, however, the welding puddle was kept at an angle of from 10 to 15 deg. off center by turning the shell as required, the welder remaining in the same position.

The method of providing for contraction was considerably different from that employed on the longitudinal seams. In the latter case it will be recalled that the seam was spread at the open end and allowed to contract as the weld progressed. On the girth seams, on the other hand, since an equidistant spacing had been provided, a more rigid type of joint had to be made. Since, however, a spacing of $^1/_2$ in. was provided before tacking, the weld was allowed to contract in small increments, and the effect of this contraction was largely prevented from being transmitted to the unwelded portion of the seam because of the wedge clamps and tack welds used. This method prevented the locked-up stresses from building up in such magnitude as to give any trouble.

In welding the second side of the double vee, furthermore, any locked-up stresses caused by welding the first side were dissipated through the reheating of the welded area, both by the preheating medium and the oxyacetylene blowpipe.

The application of this method was carried on in the following manner:

The wedge clamps were removed for a distance of about 18 in. from the starting point of the weld. As the weld progressed, other wedge clamps were removed in such a way as to maintain a spacing of about $^1/_4$ in. a foot ahead of the point of welding. To do this it was necessary sometimes to weld within about 4 in. of a wedge clamp before removing it, and the upright portion of the clamp, in this case acting as a wedge, had to be removed by cutting it out with the blowpipe. As the weld approached one of the tacks, however, the spacing between the plates edges naturally increased, and it was therefore a comparatively simple matter to control the contraction.

PROVIDING VENTILATION

It had been learned from previous experience in fabricating welded pressure vessels that as long as a cylindrical portion remained open at both ends, no trouble would be encountered in keeping the welder cool and providing ample ventilation. In welding the inner vee of the head seams and particularly in making the last inner-vee weld, however, special ventilation facilities were provided so as to give the welder fresh air at all times. In making this weld, furthermore, two operators alternated, each welding for about twenty minutes at a time.

TEST OF TANK

On the completion of the tank it was first given the regular hydrostatic test imposed on all welded pressure vessels. This consisted in applying a pressure of 600 lb. (twice the designed working pressure) and hammering all the welded seams with a 12-lb. sledge. The pressure was then increased to 900 lb. (three times the designed working pressure). It might be pointed out here that since the A.S.M.E. Unfired Pressure Vessel Code allows a design fiber stress of only 5600 lb. per sq. in., the fiber stress at the required test pressure would only be 16,800 lb. per sq. in. On this tank the fiber stress at the test pressure was 27,000 lb. per sq. in., or about 60 per cent greater than called for in the code.

During these tests strain-gage measurements were taken at various points on the tank. The stresses about the knuckle, which ordinarily is a point of maximum strain, did not pass the yield point. It might be said here that previous measurements taken on standard dished heads show that the yield point of the material at the knuckle would have been reached before a test pressure of $1^1/_2$ times the working pressure was secured.

Following the completion of the hydrostatic tests, the vessel was subjected to an air pressure of 450 lb. per sq. in. Under this pressure all the welded seams were tested with soapy water, and as usual, not a single leak was evidenced.

GENERAL DISCUSSION OF THE FACTOR OF SAFETY

I have attempted to point out thus far how the factors comprising the term "procedure control" were applied in this given instance. It is my intention now to indicate how, by the analysis of these factors, valuable progress can be made. Let us consider the question of *design*. When we first started to apply procedure-control methods to the construction of welded pressure vessels, we were of course dependent in the question of design on general codified and accepted standards. In so far as design of heads, manholes, and other outlets was concerned, therefore, we accepted the standards laid down in the A.S.M.E. Unfired Pressure Vessel Code for Riveted Construction.

The extremely high test pressures to which all welded pressure vessels are subjected, backed up by strain-gage measurements taken at various points on the vessels, however, brought out certain weak points in design hitherto believed to be entirely satisfactory, namely, at the head, knuckles, and about large outlets such as manhole openings. An extensive investigation on these two points of design was made and the resulting findings published in the May and June issues of MECHANICAL ENGINEERING. As a result, we have changed our designs accordingly so as to eliminate these weak points. I believe you will agree with me that the controlling factor in any design should be based upon the weakest point in the vessel. We can, we believe, with reasonable justification now say that we have reached a point in design where this objective has been attained.

Another point I should like to bring to your attention concerns the *test* which is imposed on all welded pressure vessels constructed in accordance with procedure-control methods. You will note that we require a severe impact test at twice the designed working pressure. No one realizes the severity of this test until he has actually seen it imposed. We then require the pressure to be raised to three times the designed working pressure, and in so doing test the tank to a point where we arrive at a known factor of safety of three. The question of the uniform strength of welded construction has often been brought up by some such statement as, "granting a weld can be made which will have a tensile strength of between 50,000 and 60,000 lb. per sq. in. or above, how can we be sure that every inch of the weld metal deposited will have this same strength?" A reasonable answer to this question is given in the careful manner in which we supervise the welding so as to make sure that only qualified and conscientious welders are employed. To convince those skeptics, however, who will not accept the reasonableness of this statement, I believe there is no more convincing argument than that with a known factor of safety of three on the vessel, proved by the tests, there can be no question as to its safety in operation. I say this because when we talk of factor of safety in general we mean an assumed factor of safety, and, in practice, actually an unknown factor. The fact that failures in other pressure-vessel constructions are of such small percentage is because the assumed factor of safety of five is sufficiently high in virtually all instances to make allowances for every conceivable irregularity in design, construction, or operation.

As we have previously pointed out, however, the vessels which are being constructed in accordance with the A.S.M.E. Boiler Code today have points of local stress concentration which would cause them to fail under repeated applications of a test pressure far below the assumed pressure at which the factor of safety of five is based, and in many instances even below a pressure equivalent to a factor of safety of three. Are we not then justified in saying not only that welded pressure vessels constructed in accordance with procedure-control methods are perfectly safe for operation, but that they are probably safer than any other present form of fabricated-plate pressure-vessel construction?

Advantages of Standardization

STANDARDIZATION enables buyer and seller to speak the same language and makes it possible to compel competitive sellers to do likewise.

In thus putting tenders on an easily comparable basis, it promotes fairness in competition, both in domestic and in foreign trade.

It lowers unit costs to the public by making mass production possible, as has been so strikingly shown in the unification of incandescent lamps and automobiles.

By simplifying the carrying of stocks, it makes deliveries quicker and prices lower.

It decreases litigation and other factors tending to disorganize industry, the burden of which ultimately falls upon the public.

It eliminates indecision both in production and utilization—a prolific cause of inefficiency and waste.

It stabilizes production and employment, by broadening the possible market, and by making it safe for the manufacturer to accumulate stock during periods of slack orders to an extent which would not be safe with an unstandardized product.

By focusing on essentials, it decreases selling expense, one of the serious problems of our economic system.

By concentrating on fewer lines, it enables more thought and energy to be put into designs, so that they will be more efficient and economical.

By bringing out the need of new facts in order to determine what is best, and to secure agreement on moot questions, it acts as a powerful stimulus to research and development—and it is thus in decided contrast to crystallization resulting from fixity of mental attitude.

It is one of the principal means of getting the results of research and development into actual use in the industries.

It helps to eliminate practices which are merely the result of accident or tradition, and which impede development.

By concentration on essentials, and the consequent suppression on confusing elements intended merely for sales effect, it helps to base competition squarely upon efficiency in production and distribution and upon intrinsic merit of product.—P. G. Agnew in a paper before the First Machine Tool Congress, Cleveland, Ohio, Sept. 19–22, 1927.

What Is the Limiting Temperature in Central-Station Operation?

By V. T. MALCOLM,[1] INDIAN ORCHARD, MASS.

As a result of his investigations the author believes that at each temperature of a metal under test there is a stress which if exceeded will cause fracture, though equipment may give satisfactory service operating at this temperature with loads greater than the critical stress for many years.

His present conclusions are that the design of equipment must be based upon the strength of metals at operating temperatures, over long periods of time, and that other properties such as thermal expansion, thermal conductivity, chemical stability, resistance to wear and abrasion, etc. must receive greater attention than in present engineering practice. These latter factors will probably govern actual design, but the first and basic requisite is that of physical strength at the proposed temperature.

The paper includes ten charts giving data on certain alloys that the author considers safe for operation at 1000 deg. fahr., and which are satisfactory in such service as regards wear resistance, chemical stability, and coefficient of expansion.

DURING the past several years considerable thought has been given to the use of increased temperatures in the operation of central stations, but as yet engineers have hesitated to design a station of this type because of the alleged inability of metals to withstand temperatures above 750 deg. fahr.

It is the author's intention in presenting this paper simply to set forth certain facts which should be borne in mind when considering the use of metals at high temperatures, rather than to describe methods of test or to delve into the peculiar characteristics of various alloys.

Materials are certainly available for use at 1000 deg. fahr., and while there is room for a difference of opinion in the matter, it is submitted that this difference can hardly be extreme, and it is hoped that as a result of its discussion the engineer will give serious thought to the use of metals at temperatures above 750 deg. fahr. in the steam station, as certain manufacturers of equipment are only waiting for him to decide.

The following paragraph appeared in an editorial in *The Engineer* (London), March 11, 1927, and the author believes it to be pertinent:

> Progress is hampered by the inevitable inertia of established practice, and practice has settled down to a maximum of 750 deg. fahr. as there is a prevalent opinion that this is about as high a temperature as can be used without undue risk. When the subject superheat is under discussion, any one advocating a higher temperature is regarded as somewhat of an enthusiast and somebody is almost sure to remark complacently that the engineer is now waiting for the metallurgist presumably to discover some new and wonderful alloy that is heat-resistant. We should all like to see the ideal metal, possessing, as it would have to do, innumerable contradictory qualities, but it is not wise to sit down and wait for it. It is much more to the point to make the best of such metals as we have, and to believe, until we have definite proof to the contrary, that progress is still possible with the use of existing metals. For if we cannot use high temperatures, the limit of possible efficiency of the steam plant has been obtained. Therefore, what is the limiting temperature? That higher temperature can be used with safety has been proved.

In a paper presented before the International Union of Producers and Distributers of Electrical Energy at the Rome, Italy, convention, Sept. 21 to Oct. 4, 1926, A. E. Rauber, superintendent of the Gennevilliers Station, Paris, France, stated that manufacturers of power-plant equipment in France are ready to accept contracts up to 850 deg. fahr., and are preparing for further advances in temperature.

Therefore, as the author sees the problem in this country, the temperature limit is a matter of opinion based on examination of available information on metals. The subject has many ramifications, and a perusal of its extensive literature discloses many inconsistencies and contradictions which are difficult to bring into agreement by any reasonable explanation, and which in some cases are so opposed to each other as to arouse suspicion regarding the accuracy of the investigation. To many, impressed by present difficulties, a temperature of 1000 deg. fahr. for use in steam plants may appear high; but when dealing with ultimate limits we are surely allowed to grant the possibility of advance, particularly in a direction in which so much progress has been recorded in the recent past. The same misgivings we have at present were obstacles not long ago when the limit was raised from 550 to 750 deg.; but, with the use of 700 to 750 deg. successful performance is now obtained with ordinary metals without calling on any of the newer alloys. In this the author has not ignored the extreme difficulty of such an advance, and it will be noted upon examination that the limit mentioned is more a matter of consolidating present achievements than a great advance beyond them.

There is very little doubt that guessing and unsupported assumptions have been liberally indulged in, but it is certain that no solution of the problem is likely to command acceptance unless backed by specific established facts. Therefore any theory that fits certain metallurgical problems, but is not backed by actual practice, should not be rashly advanced.

The complexity of the problems involved, as related to design and operation, has in a number of instances not been fully appreciated, and the construction of certain apparatus in use today at high temperatures is the result of practical experience. As Mr. Herry states in regard to his experience at Langerbrugge, he refused to see "the lions in the way" and adopted a steam temperature of 840 deg. fahr., while superheater tubes operating at 1000 deg. have been successful after months of service.

Greater economy and security in central-station development require the designing engineer to have an accurate knowledge of metals under stress at elevated temperature, and lack of this knowledge gives rise to a critical situation, as the degree of success of a metal must be measured by its stability under working conditions. The fundamental principles involved are now recognized, and a vast amount of working data has been accumulated, segregated, and tabulated; and these, together with the remarkable properties of the several alloys, are certainly making for an economy and safety in the operation of high-temperature plants heretofore thought impossible, and will in time, as the result of continuous research and practice, make possible the use of higher temperatures not thought feasible at the present time. These experimental data have been checked against operation and have proved relatively satisfactory.

The object of all investigations in high-temperature work should be to provide a measured objective basis for practice and progress, and no measurable part of an investigation should

[1] Metallurgical Engineer, The Chapman Valve Mfg. Co.

Presented at a meeting of the Metropolitan Section of the A.S.M.E., New York, January 30, 1928.

be left unmeasured if the work is to command the confidence of those for whom the investigation was made. Technical industry and the research laboratory are beginning to understand each other, and many of the highest hopes of industry are based on the prospect of intimate cooperation.

Special metals cannot fail to be of importance in affecting the destinies of engineering progress, and developments in this direction should be of great interest, especially if noteworthy advances are to be made. It has not been a difficult matter to increase pressures, because they can be taken care of by simply increasing the thickness of metal, but higher temperatures will have to be arrived at much more slowly and with greater caution.

Physical Properties of Materials Suitable for High-Temperature Service

The foremost and probably one of the most important of the engineering problems awaiting solution is that of the strength and elasticity of metals at elevated temperatures.

Broadly speaking, the solution of this problem would place us in a position to determine certain principles and the answers to many questions, particularly the cause of corrosion and the effects of temperature.

We know from past experience that methods of test as applied to metals at normal temperatures are misleading when employed in high-temperature investigations, because of the softening effect produced at high temperatures. In precise testing it will be noted that the volume of steel does not remain constant but increases, and this disturbance tends to show that a molecular change takes place when the metal is strained as well as possible changes in the relation of certain microconstituents, which are brought about by changes in density in the metal.

We know that for every stress, no matter how small, there is a corresponding strain or deformation in the body acted upon, which strain increases as the stress is increased. The stress and corresponding strain are directly proportional up to a certain point, which is the limit of proportionality, below which by removing the stress the corresponding strain will disappear and the metal is said to be "elastic." However, it must be remembered at this time that the limit of proportionality depends on the sensitiveness of the instruments used and the accuracy in carrying out the test, otherwise discordant results will be obtained. When metal is deformed beyond the proportional elastic limit it is said to be overstrained; this overstrain may be considered as a part of the total elastic deformation of the metal remaining after the external load has been removed, and when added to the permanent deformation due to plastic action will give the permanent deformation. These important characteristics, from which designs may be calculated, may be determined more or less readily.

When the same tests are applied at high temperatures it is found that ordinary steels no longer possess the same elasticity and as the temperature is increased the yield point loses definiteness and finally vanishes altogether. Furthermore, on carrying out the tests to destruction, fracture occurs at a much lower maximum stress than at normal temperature, and is more readily accomplished if the test is carried out slowly than at a more rapid rate.

It has been proved that if a load applied at any particular high temperature is gradually reduced a stress is reached at and below which no "creep" or "flow" is produced, no matter how long this stress is maintained. The term "flow" or "creep" must be used advisedly, because there is in most cases a slight "creep," not more than half of one per cent. Under continued loading at this critical stress this set becomes permanent and no further "creep" occurs.

The author's investigations have shown that there is a critical stress at each temperature, at which the metal may "creep," and that it continues to deform under continuously applied load; but in time this creep will drop to zero and continue there, while above this stress the metal will creep rapidly until final fracture.

Therefore it is the author's belief that at each temperature of the metal tested there is a stress which if exceeded will cause fracture, though equipment may give satisfactory service operating at this temperature with loads greater than the critical stress for many years.

In summing up the results of creep tests three distinct types of stress may be noted:

1 A creep stress at which the flow of metal may be quite great
2 A creep stress which shows a certain amount of deformation—up to 3 per cent
3 A creep stress or critical stress at which no appreciable creep takes place.

Therefore the correct determination of the creep stresses is most useful in providing the engineer with data on which he may base his designs. The results shown by the creep test may appear very low, but they are the safer designing stresses.

Before concluding this portion of the paper the author must emphasize the importance of these tests, because the rapid decrease in the strength of metals is not as yet sufficiently appreciated, and it must be recognized that the time factor is of great importance in the determination of the maximum allowable stress. He believes that from results of these creep tests a relation will be established in the near future between them and the short-time tests which will provide the engineer with a rapid method of determining the strength of metals at the elevated temperatures to which they will be subjected to in service, and which will eventually result in the use of the best metals for a specific case.

His present conclusions are that the design of equipment must be based upon the strength of metals at operating temperatures, over periods of long time, and that other properties such as thermal expansion, thermal conductivity, and chemical stability must receive greater attention than in present engineering practice. These latter factors will probably govern actual design, but the first and basic requisite is that of physical strength at the proposed temperature.

Chemical Stability

Excellent physical properties at elevated temperatures, however, are not the only criteria to be used in selecting metals for this service, as scaling and oxidation are decided factors. The real difficulty in connection with high-temperature work is the combining of the necessary physical properties with some particular chemical stability so as to have correct design for a complete working unit.

Problems of corrosion at high temperatures, while not so formidable as under ordinary conditions, are far more difficult to solve because of the greater chemical affinity at elevated temperatures, or the disturbing of the chemical equilibrium due to operating difficulties. Only under ideal conditions can problems of oxidation be considered apart from the accelerating effects of other elements than oxygen. The presence of other gases or compounds increases the rate of oxidation, depending upon what metals or conditions are involved.

Therefore, on account of the field being so broad and because of other difficulties, the work of investigators should be that of narrowing down the field of alloys and indicating the trend of progress.

Thermal Expansion

Thermal expansion is one of the most important points that

has a direct bearing on design of equipment for safe operation at high temperatures, because it is a well-known physical law that when heat is applied to a body, expansion takes place in all directions. It is also a well-known fact that when heat is abstracted from such a body, contraction takes place accordingly. We can reasonably assume that most failures taking place at high temperatures are caused by the use of a combination of metals that are entirely unsuited for the work or, from the lack

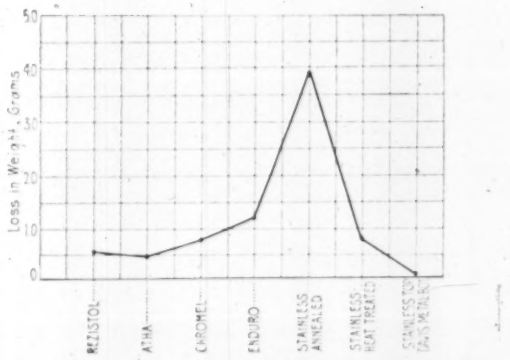


FIG. 1 RESULTS OF WEAR TESTING ON THE SEVERAL ALLOYS
(Wear tests of two 2 in. × 1 in. specimens sliding on each other under a load of 100 lb. per sq. in.; 4000 strokes.)

of knowledge on the part of the designer of certain stresses, not readily calculated due to the non-uniformity of temperature distribution. In the author's opinion, the necessity of the cycle of operation from normal temperature to high operating temperature is a factor that limits more than any other the "life" of a metal in high-temperature service.

When thermal-expansion stresses exceed the proportional limit of a metal they produce certain deformed areas which are set for the highest operating temperature of the cycle and are likely to cause failure when the temperature returns to normal after a number of repeated cycles.

As an example, when steam or hot gases are admitted to pipe lines and all points are heated to a high temperature, the result is stretch or expansion in the stud bolts in the flanges. When the line is shut off, all parts cool, and if the stud bolts return to their original length as when first "drawn up" the joint will be tight; but if they have taken a permanent set due to expansion stresses (in combination with other stresses) beyond the proportional limit the bolts will be overstrained, and of course will not return to their original length, and the joint will leak. When joints leak they are again "drawn up," and this operation is repeated until finally the strains set up are so great that the bolts fail, the fracture being crystalline.

It is no easy matter to avoid deformations caused by temperature stresses which are primarily due to operation or to lack of knowledge in design, so that certain destructive conditions must be accepted in all high-temperature work.

WEAR AND ABRASION

Despite the difference in effect observed by different investigators with various test methods, there are a number of general conclusions which may be drawn from these studies of erosion and wear. Fig. 1 is a summary of certain tests upon various metals. As shown in this figure, hardness appreciably improves performance, but hardness itself is no certain criterion of the erosion resistance of various metals as this depends to a great extent upon the structural composition, and extremely hard metal is unsuitable to resist shock on account of its brittleness. Hardened steels that have been tempered, while not so resistant, are far superior for severe service conditions on account of their toughness, and this toughness certainly is a factor that tends to resist erosion and wear.

Resistance to erosion does not, in general, increase directly with strength or hardness. Both hardness and toughness are important factors in determining the wearing qualities of a metal because hardness increases resistance to penetration, scratching, and displacement of the metal, while toughness makes it difficult to tear off small particles of the metal, which particles, when torn off by rubbing or sliding action, constitute an abrasive of considerable effectiveness.

Therefore a metal which has a certain amount of hardness combined with good impact value, denoting toughness, is better suited to resist erosion and wear than one possessing only great hardness.

It has been found by experiment and also practice that when similar metals of the same hardness are rubbed together, they will not slide under pressure without "seizing" or "galling," especially at high temperatures, although no explanation of this phenomenon is yet available. This condition probably accounts for the fact that when stainless disks and seats of the same hardness have been used in valves, the faces of the disks have been scored or roughened and in a number of cases severe "galling" has taken place. Fig. 2 shows what happens to valve disks when "seizing" takes place.

In his company's experimental work the author finds that by lowering the hardness by varying the heat treatment between seats and disk, "galling" may be reduced to a great extent, and

FIG. 2 "SEIZING" AND TEARING OF VALVE DISK
(Both rings and disk were of the same hardness.)

in the steam plant this tendency to "gall" may be mitigated by making the seats of a ferrous alloy and the disk face of a nickel-copper alloy, because with this combination there is absolutely no tendency to "seize." As wear is more severe on the seat than on the face of a disk, the latter being out of the path of steam when a valve is fully opened, the more resistant metal should be used for seats.

In conclusion, it must be remembered that any hardness produced in steel by quenching and tempering will be lost in service if the tempering necessary to produce the required hardness has been carried out at temperature below the operating temperature.

It is not the author's intention to discuss the merits of various alloys at this time except to call attention to the fact that there are certain types of alloy steels—the low-carbon-chrome steels that may be hardened and the high-nickel-chrome steels that

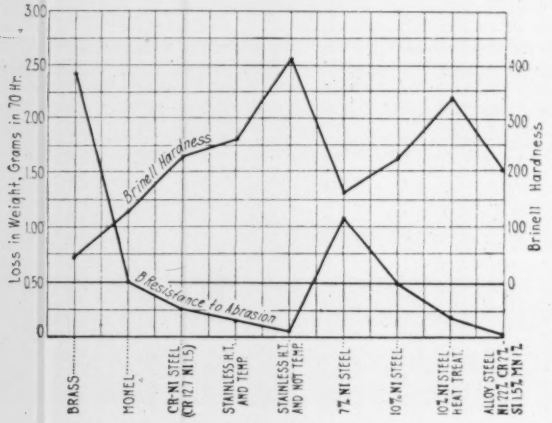

Loss in Weight, Grams in 70 Hr.
Brinell Hardness
Brinell Hardness
% Resistance to Abrasion
BRASS
MONEL
CR-NI STEEL (CR 12.7 NI 1.5)
STAINLESS H.T. AND TEMP
STAINLESS H.T. AND NOT TEMP.
7% NI STEEL
10% NI STEEL
10% NI STEEL HEAT TREAT.
ALLOY STEEL NI 22.2 CR 0.2 SI 1.55 MN 1.2

Fig. 3 Corrosion and Erosion of Steam-Turbine Blading
(From *Brown Boveri Review*, vol. 11, no. 12, p. 263, Dec., 1924.)

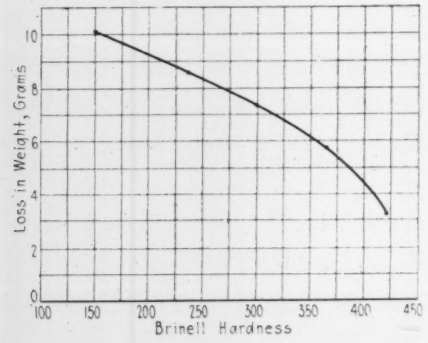


Fig. 4 Relations Between Wear and Brinell Hardness
(Test made on heat-treated stainless iron.)

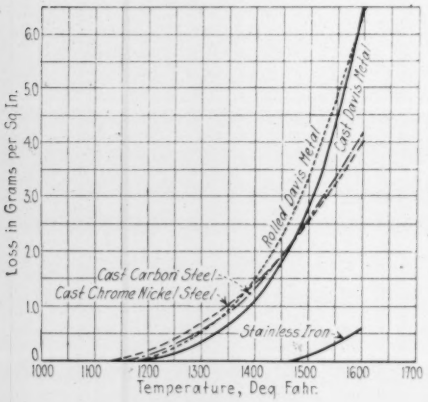


Fig. 5 Scaling Tests at Elevated Temperatures on Various Materials. Length of Test, 100 Hr.

are not susceptible to hardening—and certain nickel-copper alloys which are fully capable of service at 1000 deg. fahr.

Considerable information has been published in the last few years with regard to special qualities possessed by these various steels, and included in Figs. 6 to 16 are charts giving data on certain alloys that the author considers of value and safe for operation at 1000 deg. fahr.—always of course depending on the critical stress used in design. These alloys have the other qualities such as wear resistance, chemical stability, and coefficient of expansion of such degree that they can be used together.

In concluding, the author would quote what Faraday said a century ago:

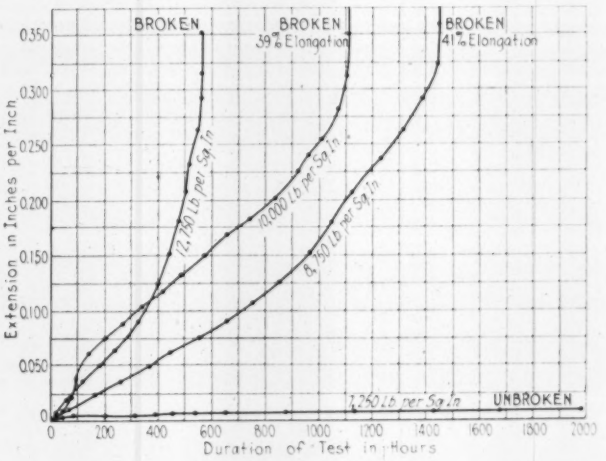


Fig. 6 Creep Tests on Wrought Chrome-Nickel Steel at Constant Temperature (1000 Deg. Fahr.) and Constant Load
(C, 0.30; Cr, 0.49; Ni, 1.33. Quenched from 1525 deg. fahr. and drawn back at 1100 deg. fahr.)

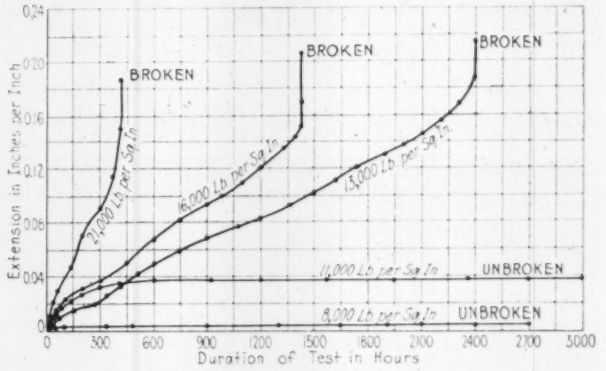


Fig. 7 Creep Tests on Cast Chrome-Nickel Steel at Constant Temperature (1000 Deg. Fahr.) and Constant Load
(C, 0.31; Si, 0.36; Mn, 0.76; Cr, 0.78; Ni, 1.95. Heat treatment consisted of normalizing to 1725 deg. fahr. and drawing at 1100 deg. fahr.)

The philosopher should be a man willing to listen to every suggestion, but determined to judge for himself. He should not be biased by appearance; have no favorite hypothesis; be of no school; and in doctrine have no master. He should not be a respecter of persons but of things. Truth should be his primary subject. If to these qualities he adds industry, he may indeed hope to walk within the veil of the temple of nature.

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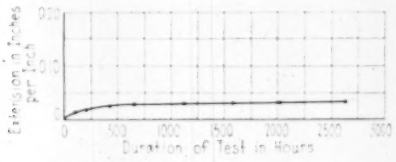
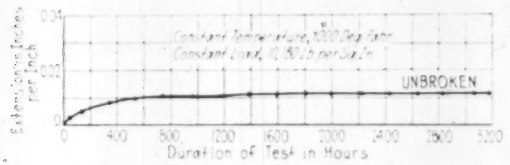
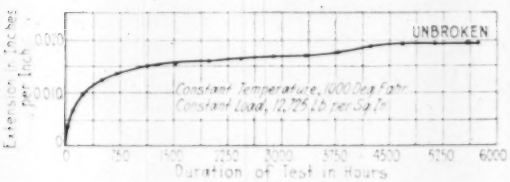


FIG. 8 CREEP TESTS ON WROUGHT CHROME-TUNGSTEN STEEL AT CONSTANT TEMPERATURE (1000 DEG. FAHR.) AND CONSTANT LOAD (10,180 LB. PER SQ. IN.)

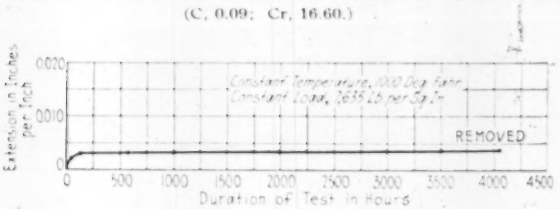
(C, 0.34; Mn, 0.75; Cr, 0.69; W, 0.73. Heat treatment consisted of quenching from 1575 deg. fahr. and drawing back at 1250 deg. fahr.)

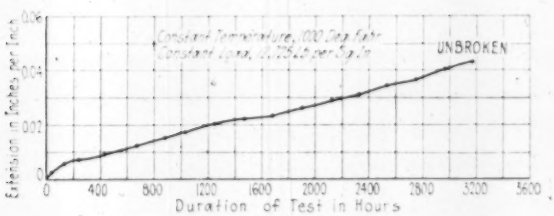




FIGS. 9 AND 10 CREEP TESTS ON WROUGHT ENDURO METAL

(C, 0.09; Cr, 16.60.)





FIGS. 11 AND 12 CREEP TESTS ON WROUGHT DAVIS METAL

(Cu, 67.25; Mn, 2.10; Ni, 28.30; Fe, 2.25.)

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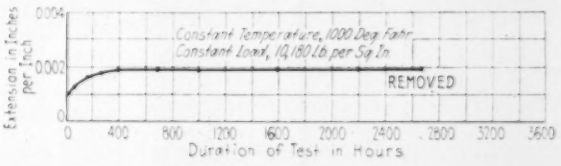
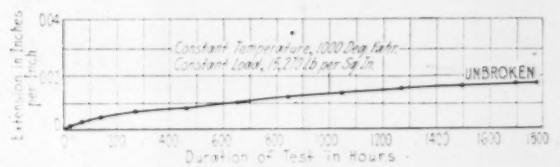
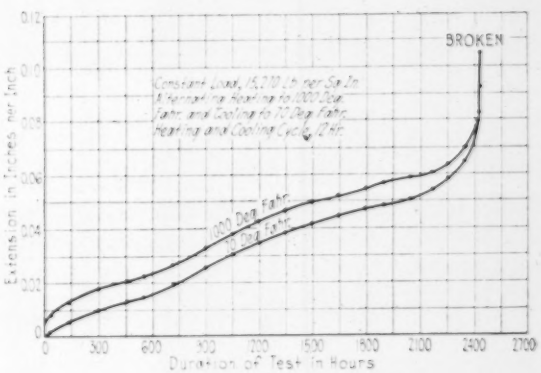
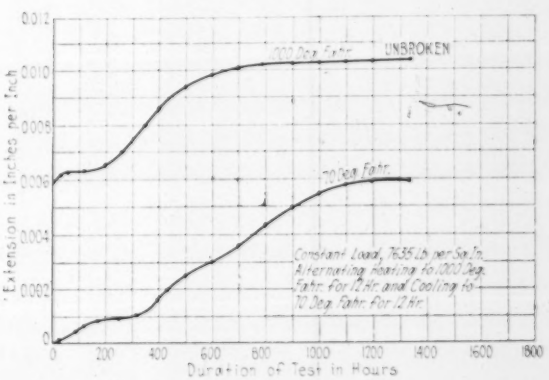

Extension in Inches per Inch
Constant Temperature, 1000 Deg Fahr
Constant Load, 10,180 Lb per Sq In
REMOVED
Duration of Test in Hours


Extension in Inches per Inch
Constant Temperature, 1000 Deg Fahr
Constant Load, 15,270 Lb per Sq In
UNBROKEN
Duration of Test in Hours

FIGS. 13 AND 14 CREEP TESTS ON LOW-CARBON STAINLESS IRON

(C, 0.09; Cr, 12.89. Heat treatment consisted of quenching from 1750 deg. fahr. and drawing at 1100 deg. fahr.)


Extension in Inches per Inch
BROKEN
Constant Load, 15,270 Lb per Sq In
Alternating Heating to 1000 Deg Fahr and Cooling to 70 Deg Fahr
1000 Deg Fahr
70 Deg Fahr
Duration of Test in Hours


Extension in Inches per Inch
UNBROKEN
1000 Deg Fahr
70 Deg Fahr
Constant Load, 7635 Lb per Sq In
Alternating Heating to 1000 Deg Fahr for 12 Hr and Cooling to 70 Deg Fahr for 12 Hr
Duration of Test in Hours

FIGS. 15 AND 16 SPECIAL ALTERNATING HEATING AND COOLING CREEP TESTS ON CAST CHROME-NICKEL STEEL

(Analysis and treatment same as given in Fig. 7.)

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Engineering Research and the Engineering Foundation

THIS IS the last of series of five little articles on the Engineering Foundation, telling what it is doing and what it hopes to do. The Foundation is hopeful for the future because of the very real need for such engineering research as it can encourage and because of the proved generosity of engineers and those who profit by engineering. No one expects the finances of the Foundation to reach anywhere near the prodigious amounts disbursed annually in the interests of public health by the Rockefeller Foundation (nearly $10,000,000 was thus disbursed in 1926). But the reasonable hope is entertained that the present endowment of considerably less than a million will grow to $5,000,000. This principal would assure a dependable and permanent income sufficient to lend generous aid to needed engineering research throughout the United States. The benefits spread also to other countries the world around.

A philanthropic person who desires to help research in science or engineering can, of course, if he has enough capital, establish a private foundation and perpetuate his own name. This system of doing things did not appeal to Ambrose Swasey, but appealed to the Mellon family at Pittsburgh and to William Boyce Thompson at Yonkers.

Or, the philanthropist can make a gift to a college of engineering—as Mrs. Phoebe Hearst did at Berkeley, or Daniel Guggenheim did in founding New York University's school of aeronautics, or as several grateful friends did recently to Lehigh University. Where there is a personal tie, such a method of giving is admirable. For example, it was recently suggested to Thomas A. Edison that he endow a professorship in the History of Science at the Hall of Fame, where he undoubtedly will be elected to a place.

Or, the philanthropist can follow the examples of Ambrose Swasey, Henry R. Towne, and Edward Dean Adams, and contribute to Engineering Foundation, trusting in the good sense of the great national engineering societies to assist engineering research with judgment and vision. The Foundation is controlled by a board composed chiefly of eminent engineers chosen from the American Society of Civil Engineers, the American Institute of Mining and Metallurgical Engineers, The American Society of Mechanical Engineers, and the American Institute of Electrical Engineers. The director of the Foundation, Alfred D. Flinn, was formerly deputy chief engineer of the Board of Water Supply of the City of New York.

It is fitting to quote an idealistic conception of the Foundation's future as depicted by its director: "So long as humanity is dependent upon Nature.....so long as there is intelligence to utilize Nature's materials and forces, the resources of the Foundation will be wisely administered.....Whithersoever the quest of knowledge of Nature's resources may lead, wheresoever attempts may be made to apply that knowledge to the service of man, through engineering and industry or other channels, thither may the Foundation direct its energies." This, briefly, is the inspiriting vision which Engineering Foundation holds for the future—the guiding torch under whose enlightening beams its researches are initiated and carried on. Obviously there is keen need for an institution thus inspired and gifted in America of the twentieth century. There is hopeful confidence in the minds and hearts of those identified with it that the Foundation will grow and broaden in aiding science to ameliorate the lot of mankind.

P. B. M.

The Cost of Blowdown of Boilers

WHEN ordinary water is used in a boiler some of it will be exhausted as steam while the solids remain. When the dissolved and precipitated impurities reach a certain concentration it becomes necessary to blow down the boiler so as to prevent foaming or forming of scale, or both. This concentration, which may be called the blowdown point, will vary considerably with the different waters, load conditions, etc. and may also be influenced by the use of anti-foaming compound.

In discussing this problem the author gives a formula for the quantity of feedwater required and the quantity of feedwater blown off. The available tables for determining the cost of blowdown fail to take into account the fact that the total amount of feedwater for a given run under otherwise identical conditions will vary with the amount of impurities. To correct this omission the author bases his formula and diagrams upon the cost of blowdown per 1000 gal. of water (8340 lb. of steam) actually used. He then gives a formula for the loss through blowdown and graphs showing the cost of blowdown in boilers where the content of impurities is taken care of. (R. A. Tanner, Asst. Engr., Northern Pacific Railroad, in *Railway Mechanical Engineer*, vol. 101, no. 11, Nov., 1927, pp. 712–713.)

Some Essential Principles for Budgetary Control

By HAROLD VINTON COES,[1] CHICAGO, ILL.

This paper presents in condensed form many of the essential principles for the application of budgeting to a business and the effective means for control. Some of the means for securing budgetary control are shown in charts and statements of the following: (1) fundamental operating relationships, (2) comparative results of operation for different sales volumes, (3) manufacturing expense budget, (4) indirect labor control, (5) sales and production coordination, (6) sales quota, (7) department quota, (8) comparison of operating ratios.

THIS paper is presented with the idea of endeavoring to reduce to as few words as possible many of the essential principles for the application of budgeting to a business, and the effective means for control.

Coordinated Intelligence

Utilize those methods that will combine effectively the coordinated intelligence of the entire organization behind a predetermined plan.

Analysis

Analyze past operations, past performance, past expenditures, sales, etc. in fact all those phases of the business that it is proposed to budget.

Synthesis

Build up from the facts developed by analysis the trends and tendencies of the past.

Judgment

By rational judgment ascertain and isolate those factors that will influence the course of the business in the future.

Initial Control

Ascertain the places where control can be most effectively obtained initially in the method, procedure, recording, and performance.

Operating Ratios

There is no uniform set of standard ratios expressing the various fundamental relationships between expenses and sales, manufacturing expense and cost of sales, etc. These must be determined for each individual business from the study of past records, and then checked against such ratios for the industry or important units in the industry as can be obtained. The application of these previously determined ratios then to the various items of expense in various divisions of the business will constitute the budgeted expense items.

Relationship of Phases in Business

Develop the fundamental relationship between the various phases of the business, such as ratio of manufacturing expense to net production, to net sales, distribution expense to net sales, and the like.

Adequate Accounting

A prerequisite to successful budgeting is adequate accounting and statistical records, for budgeting is dependent upon all the recorded data of regular routine wherein past performance may be determined and future possibilities outlined.

Organization

Realign the duties of the organization so that duties and functions are logically grouped.

Corelationship of Activities

Budgetary control correlates the activities of the various functions of the business through executive control to prevent over, undue or lack of emphasis on some important phase of the business.

FUNDAMENTAL OPERATING RELATIONSHIPS

Ratio	Year 1922	1923	1924	1925	1926	Max. or Min., per cent
	Per cent					
Cost of Sales / Net Sales	79.9	79.2	78.1	77.8	80.1	75
Mfg. Expense (Burden) / Net Production	29.4	24.0	26.8	26.1	23.5	22
Mfg. Expense / Net Sales	24.5	22.0	24.3	24.7	20.2	20
Raw Material Inventory / Net Production	40.1	42.0	41.9	39.8	38.9	35
Process Inventory / Net Production	30.1	32.0	31.0	29.9	29.2	26
Direct Material / Net Sales	37.5	35.2	37.2	38.5	39.1	35
Direct Labor / Net Sales	23.4	22.8	20.9	21.7	22.0	20
Indirect Labor / Direct Labor	47.0	46.5	46.1	45.8	45.2	40
Finished Goods Inventory / Net Sales	10.8	10.4	10.1	10.5	10.0	10
Total Inventory / Net Sales	24.3	24.0	23.8	24.2	23.0	20
Fixed Expense / Total Mfg. Expense	28.1	28.3	27.9	27.2	27.5	25
Working Capital / Net Sales	35.1	34.8	35.5	34.2	33.1	30
Gross Profit / Net Sales	21.1	20.9	21.9	22.2	19.9	25
Selling Expense / Net Sales	10.9	11.0	11.4	12.2	12.5	11
Net Profit / Net Sales	4.3	4.7	5.1	5.5	3.9	5

The Budget and Executives

The budget can in no way replace skilful executives, but in their hands it is an exceedingly useful tool for modern management.

Flexible Standards

The expression of results for the various phases of the business, for the departments, subdivisions, etc. should be in such terms that they are suitable to the various elements, yet flexible enough to permit ready adjustment to ever-changing conditions.

Determination of Standards

Carry the analysis far enough back over a sufficient period so that the law of averages, the swings or cycles, trends and tendencies can be fully developed; correct for those influences

[1] Vice-President and General Manager, Belden Manufacturing Company. Vice-President and Chairman of Finance Committee, A.S.M.E.

Contributed by the Management Division and presented at the Annual Meeting, New York, December 5 to 8, 1927, of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS.

COMPARATIVE RESULTS OF OPERATIONS FOR DIFFERENT SALES VOLUMES[1]

Sales, in thousands of dollars	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000
	Per cent															
Sales	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Materials	40.3	39.4	38.5	37.8	37.2	36.7	36.7	36.7	36.7	36.7	36.7	36.4	36.1	35.8	35.5	35.2
Direct labor	28.0	27.5	27.0	26.5	26.0	25.5	25.5	25.5	25.5	25.5	25.5	25.0	24.5	24.0	23.5	23.0
General factory expense	20.0	19.0	18.0	17.0	16.5	16.0	15.5	15.0	14.5	14.0	13.5	13.0	13.0	13.0	13.0	13.2
Cost of sales	88.3	85.9	83.5	81.3	79.7	78.2	77.7	77.2	76.7	76.2	75.7	74.4	73.6	72.8	72.0	71.2
Gross profit on sales	11.7	14.1	16.5	18.7	20.3	21.8	22.3	22.8	23.3	23.8	24.3	25.6	26.4	27.2	28.0	28.8
Selling expenses	8.0	7.7	7.5	7.3	7.1	7.0	6.9	6.8	6.7	6.6	6.5	6.4	6.3	6.2	6.1	6.0
Selling profit	3.7	6.4	9.0	11.4	13.2	14.8	15.4	16.0	16.6	17.2	17.8	19.2	20.1	21.0	21.9	22.8
Administrative expense	10.0	9.0	8.0	7.0	6.5	6.0	5.9	5.8	5.7	5.6	5.5	5.4	5.0	5.0	5.0	5.0
Operating profit	6.3[2]	2.6[2]	1.0	4.4	6.7	8.8	9.5	10.2	10.9	11.6	12.3	13.8	15.1	16.0	16.9	17.8

[1] By Bigelow Kent Willard & Co. [2] Loss.

Form 394-3 400 7-8-27

SCHEDULE_____

MANUFACTURING EXPENSE

DEPARTMENT_____ MONTH_____ 192__

Acct. No.	NAME	This Month	Per $100 Prod.	Last Month	Per $100 Prod.	Budget	Per $100 Prod.	Cumulative Actual	Per $100 Prod.	Cumulative Budget	Per $100 Prod.
321	Insurance										
322	Taxes										
323	Rentals										
324	Depreciation										
330	Development										
340	Power Plant Oper. Labor										
350	Power Plant Supplies										
360	Power Plant Inc. Oper. Exp.										
370	Power Plant Maintenance										
390	Power, Heat & Light Purchased										
410	Maintenance Land										
420	Maintenance Buildings										
430	Maintenance Structures										
440	Maintenance Heat. Vent. Wire.										
450	Repairs to Mach. Elec. Furn.										
451	Replacements and Improvements to Mach. Elec. Furniture										
480	Maintenance Automobiles										
	TOTAL										
	Budget Correction for Variation in Productive Labor										
	Corrected Total										
	% Actual Expense to Budget Expense										

MANUFACTURING-EXPENSE SCHEDULE[1]

201 Factory Supervision
202 Foreman & Assistants
203 Inspectors
210 Clerical Labor
211 Cost & Payroll Dept.
212 Production Dept.
213 Employment
220 Other Labor
221 Janitors, Watchmen & Elev.
226 Machine Set-Up
227 Overtime—Bonus
228 Allowances
229 Idle Time
230 Development Engineering
231 Plant Engineering
241 Fuel Consumed—Gas
242 Water
243 Lubricants
244 Non-Durable Small Tools
245 Factory Office Supplies
246 Miscellaneous Shop Supplies
247 Steam
250 Unassignable Frt.-Exp.
260 Employees' Service
270 Accident Compensation
281 Defective Workmanship
282 Defective Workmanship Cr.
283 Other Losses Due to Errors
291 Purchasing Dept.
292 Stores—Rec. Department
293 Finished Stock Department
294 Shipping Department
295 Labeling Department
296 Rewind Department
301 Rearrangement of Equip.
303 Traveling Expenses
305 Garage
306 Shop Electric Plant
307 Instruction of Apprentices
308 Unassignable Testing Expense
309 Other Manufacturing Expense
310 Belden Spool Expense
311 Foreign Spool Expense
312 Laboratory
313 Inter-Plant Expense
314 Assn. Dues and Memberships

[1] Two similar preceding forms care for items 201–314 as listed above.

SALES AND PRODUCTION—COMPARISON FOR INVENTORY CONTROL AS OF APRIL 30, 1927

Products or lines of merchandise	No.	Est. net sales for May	Net sales for April	Net sales for April last year	In stock May 1 at selling prices: Standards	In stock May 1 at selling prices: Specials	Total inventory at selling prices	Max. point this year	Inventory gain or loss in month	Inventory quota Apr. 30 at selling prices	May 1, value of orders on books	Net production for April at selling prices	Net production April, 1926, at selling prices
	1												
	2												
	13												
	14												
(All figures in thousands of dollars)					Total for High Month								

that were purely accidental, so that representative standards may be developed.

Segregation of Costs

Segregate all items of expense or cost into three groups:

1 Fixed or non-variable
2 Semi or partially variable
3 Full variable.

Break-Even Point

Develop the break-even points (points at which no profit or loss is sustained) for the expenses as budgeted for the various departments, and the corresponding volume of sales per class of product.

Production Capacities

Regardless of sales volume, determine the production capacity of the plant and break this down by departments, by sections, in well-balanced relationships. Determine it also by classes of product.

Relationship Between Productive Capacity and Sales Volume

Through the market surveys determine the minimum volume at those price levels that the market will take up, which will absorb the greatest proportion of potential productive capacity.

Product Demand

Budgeting is again dependent upon a knowledge and relationship between:

a Demand for the given product and demand for the product of the entire industry
b Demand for the individual product and its relationship to the demand for similar articles similarly marketed
c The purchasing power for which the demand can be sustained.

Budget Period

Cover the longest period with the minimum business hazard. Usually the period can be the longest for those businesses having the least hazard, and must be shortened as the business hazard increases. Its determination is fundamental and is largely contingent upon several factors, such as:

a The business risk
b The stability of the market
c The method of financing, production and inventories
d The schedule period of production
e The duration of the reporting and accounting period
f The adequacy of statistical information as to past performance and transactions
g The merchandising inventory turnover period
h The seasonal or periodical demands and fluctuations.

Revision of Budget

Budgets should be checked, compared, and revised monthly.

Control of Expense

Control can be obtained by frequent comparisons—not less than once a month—between actual and budgeted expenses, the budget of course adjusted for the legitimate expansion or contraction in sales volume or production that has occurred contrary to the predetermined budget for the period.

Limits

The budgets as adopted constitute the standards of performance for the period determined, and establish limits for the expenditures of each division and section of the business, but should not be exceeded without permission from the properly constituted authority.

Forecasts

Forecast all those expenditures, be they capital outlays or expense items, that it is proposed to control by budgets, or that will affect the phase or phases of the business to be controlled by budget procedure.

Preparation of and Responsibility for Budget Estimates

The source of information should be from the logical divisions of the business, and the responsibility for the origin and accuracy should be lodged with those charged with the responsibility for the performance of the aforesaid divisions or sections thereof.

The Sales Estimate or Forecast

This is based upon information from three sources:

1 The amount and character of previous sales—analyzed
2 The present and future market conditions, the trade situation—market analysis
3 The executive plans, policies, and administrative expense of the business.

Balancing of Production and Sales Demand

Proper sales forecasting coupled with adequate inventory control permits the application of the principle of balancing production with sales demand.

FORM 484 IM. 4-27

EXPENSES FOR_____ ACCOUNT NO._____ DEPARTMENT_____

POSITION	MO. AMT.	POSITION	MO. AMT.	POSITION	MO. AMT.	POSITION	MO. AMT.	POSITION	MO. AMT.

MONTHLY COST BELOW BUDGET: DIRECT EX._____ INDIRECT EX._____ TOTAL EX._____ PROD. LABOR $_____

MONTH	JAN.	FEB.	MARCH	APRIL	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	TOTAL
DIRECT EX.													
INDIRECT EX.													
TOTAL													
PROD. LABOR													

INDIRECT LABOR CONTROL

SALES QUOTA MONTHLY REPORT

DEPARTMENT		JAN. FEB. MAR. APR. MAY JUNE JULY AUG. SEPT. OCT. NOV. DEC.		SHIPMENTS TO-DATE	YEARS QUOTA
1	A				
	B				
2	A				
	B				
3	A				
	B				
4	A				
	B				
5	A				
	B				
6	A				
	B				
7	A				
	B				
8	A				
	B				
9	A				
	B				
10	A				
	B				
11	A				
	B				
12	A				
	B				
13	A				
	B				
14	A				
	B				
			TOTALS		

A= YOUR SHIPMENTS
B= TOTAL DEPT. SHIPMENTS

IF THE *BONUS* WAS ON A MONTHLY INSTEAD OF A YEARLY BASIS YOU WOULD SCORE _____ POINTS AND BE _____ HIGH MAN

DATE _____

SALESMAN _____

Sales Expense Budget

It is aimed to secure proper relationship and control of:

- *a* Direct sales expense
- *b* General sales expense
- *c* Advertising
- *d* Branch-house expense
- *e* Sales promotion
- *f* Foreign sales expense
- *g* Warehouse and shipping expense.

Undue emphasis is frequently placed on some one or two of these items to the detriment of the others, and to the business as a whole. Advertising and sales promotion are frequent offenders. A properly prepared and considered budget will reveal these facts, show which are out of balance, and permit bringing the several items into balance.

Production Budget

The breaking down of the sales estimate by the Production Department permits the determination of the production

DEPARTMENT QUOTA MONTHLY REPORT

DEPARTMENT	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.		SHIPMENTS TO-DATE	YEAR'S QUOTA
1	120,000	240,000	370,000	490,000	615,000	735,000	812,000	932,000	1,052,000	1,187,000	1,317,000	1,442,000			
2	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.			
	65,000	125,000	185,000	235,000	290,000	340,000	387,000	467,000	557,000	657,000	752,000	837,000			
3	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.			
	65,000	135,000	210,000	275,000	340,000	400,000	447,000	517,000	597,000	682,000	762,000	832,000			
4	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.			
	15,000	30,000	50,000	65,000	80,000	93,000	100,000	115,000	135,000	160,000	180,000	200,000			
5	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.			
	20,000	40,000	70,000	90,000	115,000	135,000	145,000	165,000	195,000	225,000	250,000	270,000			
6	JAN.	FEB.	MAR	APR	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.			
	30,000	57,000	84,000	106,000	126,000	146,000	163,000	191,000	221,000	277,000	327,000	370,000			
7	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.			
	12,000	20,000	42,000	62,000	80,000	100,000	115,000	135,000	156,000	181,000	201,000	221,000			
8	JAN.	FEB.	MAR	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.			
	50,000	50,000	70,000	85,000	95,000	100,000	110,000	140,000	190,000	260,000	330,000	380,000			
9	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.			
	22,000	42,000	62,000	79,000	96,500	113,500	128,500	147,500	170,500	199,500	226,000	251,000			
10	JAN.	FEB.	MAR	APR	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.			
	16,500	24,000	32,500	42,500	57,500	77,500	102,500	142,500	187,500	237,500	287,500	313,000			
11	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.			
	15,000	30,000	48,000	63,000	75,000	85,000	90,000	110,000	129,500	149,500	169,500	186,500			
12	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.			
	23,000	38,000	48,000	58,000	63,000	68,000	73,000	83,000	93,000	113,000	128,000	138,000			
13	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.			
	5,000	9,000	15,000	20,000	24,000	28,000	34,000	36,000	41,000	47,000	52,000	57,000			
14	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV	DEC.			
	4,000	8,000	13,000	17,000	22,000	27,000	30,000	34,000	38,500	43,500	47,500	51,500			
15	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.			
	440,500	848,000	1,297,500	1,685,500	2,079,000	2,448,000	2,734,000	3,215,000	3,769,000	4,419,000	5,029,500	5,549,000			
													TOTALS		

DATE..... 1927

estimates in total, except for goods made to special order. Ordinarily it is impractical to budget in advance special order production per se.

The principle of scheduling is then used to insure production in sufficient quantity at the proper time to satisfy the estimated sales demand, which is predicated upon:

a Operation analysis—from specifications of product

b Schedule of productive equipment with capacity per unit.

This may show that:

a Sales forecast exceeds present productive capacity under normal operation

b Sales forecast is less than present productive capacity under normal operation

c Sales forecast approximates present capacity under normal capacity,

and will necessitate reconciliation of either one or the other, depending upon the financial program.

This brings in inventory control, since it is usually impossible to so accurately forecast sales demand and schedule production as to have the two so synchronized as to accurately meet sales demand.

Excessive production beyond immediate sales demand runs up the inventory and ties up working capital. Inadequate production causes poor service to customers and lost sales, and consequently lost income. Hence adequate inventory control is of prime importance.

Balanced Inventory

Properly apportioned and balanced inventories are then a prerequisite to satisfactory budget operation, and these are brought about by adequate and comprehensive budgetary control.

various classes of product. By then stating the dollar volume in the sales estimates, adjusting for cost of sales, and applying the labor ratios, a fairly approximate labor budget can be set up.

By using similar ratios for the relationship of direct to indirect labor, the indirect labor budget can be similarly prepared.

Manufacturing-Expense Budget

Where centralized production and standardized goods for stock are not the rule, probably the most practical method of dealing with the manufacturing expense is by the application of the principle of standard overhead or burden rates. Here a reserve is set up and over-absorption of burden during peak or overnormal operations is credited to the reserve, and during dull seasons, when operating at less than normal capacity, the deficiency is debited from the reserve, the whole being set so as to balance out for the year's operation.

MONTHLY COMPARISON OF OPERATING RATIOS

RATIO	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.
Net Sales Billed to Quota												
Cumulative												
Distribution Expense to Budget												
Cumulative												
Administrative Expense to Budget												
Cumulative												
General Expense to Expense absorbed												
Cumulative												
Manufacturing Expense to Budget												
Cumulative												
Manufacturing Expense to Expense Absorbed												
Cumulative												
Factory Operating Capacity to Normal												
Cumulative												

Material Budget

Since the principle of balance of stores is applied satisfactorily for the finished goods inventory control, the same principle can be applied to balance of stores records for raw material.

Labor Budget

This is the most difficult budget to prepare, particularly where goods made to order are a large proportion of the total production, since operations and combination of operations vary over wide ranges. The principle of standardized operations is applied, and where this is done one hundred per cent the preparation of the labor budget ceases to be a difficult matter.

Frequently an approximate control can be obtained by using predetermined ratios of direct labor cost in the cost of sales of

For control purposes the actual expenses should be compared, not only with the normal budget but also with the normal budget adjusted to what it would be for the actual capacity operations. Under these conditions control can be effectively obtained.

Plant and Equipment Budget

This is to prevent:

1 Overexpansion
2 Force careful considerations of capital layouts
3 Preserve proper relationship between retirements, replacements, maintenance, and depreciation reserves
   a Repairs charged to current expense—standard maintenance and standard maintenance budget

b Betterments (improvements) and additions are set up in the capital budget.

This budget would then show:

1 The estimated cost of new equipment installed and in place
2 The depreciation and anticipated repairs on new equipment
3 The depreciation and anticipated repairs on present equipment.

General and Administrative Expense Budgets

These to cover such broad classifications as:

Financial Budget

This is set up for the correlation of income and expenditures:

a An estimate of cash requirements, predicated upon the programs as set forth in the preceding budets
b Estimate of cash receipts. This is predicated upon:
  1 A relationship of sales to collections
  2 Other sources
  3 Bank loans—with program therefor.
c An estimate of cash disbursements:
  1 Material purchases (accounts payable)
  2 Factory payroll

SCHEDULE_____

DEPARTMENT

ADMINISTRATION EXPENSES. MONTH_____ 192____

ACCT NO.	NAME	THIS MONTH	LAST MONTH	BUDGET	CUMULATIVE ACTUAL	CUMULATIVE BUDGET
	Salaries:					
21	Officers-Dept. Heads					
23	Clerical Employees					
25	Treasury Dept.					
26	Gen'l. Acctg. Dept.					
27	Other Expenses					
30	Rent,Lt.Ht.Exec. Offices					
32	Office Equip,Rep & Repl.					
34	Traveling & Entertainment					
36-37	Tel. & Telg. Expenses					
38	Stat'y.-Office Supplies					
39	Donations					
41	Depreciation					
43	Legal-Consulting					
45-47	Other Expenses					
	TOTAL					
	NON-DEPT'L. EXPENSE					
147	Corporate Taxes					
148	Patent Expenses					
149	Disc. Exp on Bond Issue					
150	Accrual against Poss.Loss.					
152-154	Unabsorbed Trans.					
156	Warehouse Expenses					
	TOTAL					
	MISCELLANEOUS INCOME					
161	Interest on Notes-A/C Rec.					
162	Miscellaneous					
163	Return on Investment					
164	Purchase Discount					
165	Belden Spool Profit					
	TOTAL					
	CHARGES TO INCOME					
171	Interest on Notes Pay.					
172	Interest on A/C Pay.					
173	Interest on Bonds					
174	Sales Discount					
	TOTAL					

Form 489 500 1-25-27

ADMINISTRATION-EXPENSE SCHEDULE

a Executive
b Service or auxiliary departments
c Financial
d Non-departmental or corporate expense,

and these are predicated upon:

1 A proper main classification logical for the organization as set up
2 The incidence of these expenses and the responsibility for their origin and supervision
3 Sufficient sub-classifications to enable detection of variations and permit the focusing of responsibility.
3 Factory overhead expense (manufacturing expense)
4 Distribution expense (sales expense)
5 General and administrative expense (executive)
6 Non-departmental (corporate)
7 Capital account (new equipment, plant, etc.).

The Forecast Balance Sheet

1 Assets and liabilities
2 Profit and loss.

These two statements, then, when compared with the actual results of operation, show what the effect has been of the individual budgets and quotas on the operation of the business as

a whole, and where these have fallen below or exceeded actually the predetermined balance sheet and profit-and-loss statement.

From this master budget and individual budgets the executives can then determine why the predetermined programs fail to be realized and can apply the corrective measures required to bring them in balance. This may result in revisions of many of the individual budgets to bring this about.

Reports

Suitable reports should be set up giving estimated forecasts of predetermined budgets compared with actual results:

These reports showing the comparison between the estimated or forecast performance are taken as standard, and the actual performance renders it possible for the executives responsible to enforce the budget and keep operations correlated and in balance.

They also serve to show what plans must be made for the future for financing, for production, for sales expansion or curtailment and the future plant requirements.

Some of the means for securing budgetary control are shown in the accompanying statements and charts:

1 Fundamental operating relationships

SCHEDULE_____

DEPARTMENT

DISTRIBUTION EXPENSES. MONTH_____ 192__

ACCT. NO.	NAME	THIS MONTH	LAST MONTH	BUDGET	CUMULATIVE ACTUAL	CUMULATIVE BUDGET
	Salaries:					
51	Officers-Dept. Heads					
53	Advertising					
54-57	Selling Force, Sales Rec.					
58	Terr. Correspondents					
59	Stenographers					
60-61	Sales Engr.					
62-67	Clerical Employees					
68	Foreign Dept.					
69	Credits & Collections					
70-71	Billing & Distr. Acctg.					
73-76	Traveling & Entertainment					
77-78	Telephone & Telegraph					
79	Postage					
81	Stat'y. & Office Supplies					
84	Office Equip. Rep & Repl.					
85-91	General Advertising					
92-99	Radio Advertising					
92A-99A	Automotive Advertising					
92E-99E	Electrical Advertising					
101-103	Catalogues General					
101A-103A	Catalogues Automotive					
101E-103E	Catalogues Electrical					
101R-103R	Catalogues Radio					
106	Sales Commissions					
107	Losses due ro Errors					
109	Collections Fees					
112-113	Foreign Sales Expense					
115	Samples					
117	Depreciation					
118-119	Rent					
120-121	Other Expenses					
126-135	Newark Branch					
136-145	Cleveland Branch					

Form 499 500 5-25-27

DISTRIBUTION-EXPENSE SCHEDULE

1 Showing relationship between production and inventory, including production, sales and inventories
2 Manufacturing expense
3 Labor
4 Purchases
5 Material
6 Sales
7 Sales expense
8 General and administrative expense
9 Balance sheet
10 Income statement
11 Operating-ratio comparisons
12 Maintenance control.

2 Comparative results of operation
3 Manufacturing-expense budget
4 Indirect labor control
5 Sales and production coordination
6 Sales quota
7 Department quota
8 Comparison of operating ratios.

NOTE: For some of the material for this paper the author wishes to acknowledge his indebtedness to "Budgetary Control," by J. O. McKinsey, "Organization and Budgetary Control in Manufacturing," by Fordham and Tingley, "Financial Handbook," by R. H. Montgomery, "Management's Handbook," by L. P. Alford, *Manufacturing Industries, Industrial Management*, and the American Management Association.

Progress in Steam Research

Reports of Work at Bureau of Standards, Massachusetts Institute of Technology, Harvard University, and Schenectady

THE sixth annual session on Progress in Steam Table Research was held on the afternoon of Wednesday, December 7, during the 1927 Annual Meeting of the A.S.M.E. Dean Arthur M. Greene, Jr., Past Vice-President of the Society, presided.

George A. Orrok, Chairman of the Executive Committee, Steam Table Fund, reported on the financial status of the research; N. S. Osborne, H. F. Stimson, and E. F. Fiock told of the results of calorimeter experiments at the Bureau of Standards and of a determination there of the mechanical equivalent of the mean heat unit; and L. B. Smith gave particulars regarding the recently completed determination at the Massachusetts Institute of Technology of the *p-v-t* properties for a portion of the steam superheat region. J. H. Keenan compared the M.I.T. experimental determination of specific volumes with the values given in the A.S.M.E. table of specific volumes, and told of proposed work at Schenectady in steam-chart calculation; E. L. Robinson presented a chart of reheat factors suitable for calculations on condensing or non-condensing turbines; and H. N. Davis told of steam research abroad and gave particulars of the work accomplished at Harvard University during the past year. Chairman Greene and E. S. Mueller of the Bureau of Standards took part in the discussion of the various reports, which latter immediately follow

Report of the Executive Committee of the Steam Table Fund

GEORGE A. ORROK, Chairman of the Executive Committee of the Steam Table Fund, reported as follows:

At the December, 1926, Annual Meeting the Executive Committee of the Steam Table Fund reported receipts up to December 1, 1926, amounting to $50,625.00, with disbursements to the same date of $48,514.64, leaving a balance on hand of $2,110.36. At that time it was pointed out that the Bureau of Standards had disbursed considerable sums from its own funds in the furtherance of this investigation. It was also acknowledged that both the Massachusetts Institute of Technology and Harvard University had covered certain expenses not provided for in funds raised by the Committee. As of December 1, 1927, the financial condition of the fund stands as follows:

Receipts:	
Previously acknowledged	$50,625.00
Additional receipts	7,124.65
	$57,749.65
Disbursements:	
Previously reported	$48,514.64
Additional disbursements	7,920.07
Total disbursements	56,434.71
Balance on hand, Dec. 1, 1927	1,314.94
Total	$57,749.65

Of the $57.675 subscribed to the fund, $1000 came from the Engineering Foundation, $12,750 was given by the public utilities, represented wholly by electric light and power companies, and by far the largest amount, $43,925, was subscribed by industrial concerns. In all, the Committee has received forty-three subscriptions of which eight were second contributions by industrial firms. The receipts during 1927 were $7124.65, representing second appropriations by six industrial companies and one new subscription. A great deal of work remains to be done and additional funds are necessary to carry this important investigation to a successful close. It is hoped that many organizations who have thus far been unable to lend their financial support to the Committee will now volunteer their assistance at a crucial period, and that those who have already given their approval to this work in a substantial way will follow the example set by others in subscribing to second contributions.

The Committee is pleased to report that the early difficulties in experimental apparatus at the Bureau of Standards have now been overcome through the perseverance and patience of those responsible for that particular phase of this research. The calorimeter was finally put into operation the latter part of March and after nearly a month's preliminary training of observers in the experimental technique some two months were occupied in calibration. During July and August work at the Bureau of Standards was devoted to a determination of the mean calorie between the ice and steam points. The value of the mean calorie obtained in these experiments will be rechecked to assure its accuracy, and it is hoped that a final precision of 1 in 5000 will be obtained for this fundamental unit. Dr. Osborne reports that thus far the apparatus has met expectations and that everything points to a successful completion of their program. The work at the Bureau of Standards will not be further anticipated, as Dr. Osborne will discuss that in more detail.

At the Massachusetts Institute of Technology Professor Keyes has continued his measurements on the pressure, temperature, and volume relation in the region of high temperatures and superheats. Dr. Smith will tell in detail what they have accomplished in the past year. Professor Davis at Harvard University has been engaged in applying corrections to and calculating the results of his Joule-Thomson experiments, upon which he will later speak. Mr. Robinson will also tell of a chart prepared by him which gives reheat factors applicable to calculations on condensing and non-condensing steam turbines.

With the aid of recent data secured by Dr. Smith at the Massachusetts Institute of Technology at pressures ranging from 1420 lb. per sq. in. to 4300 lb. per sq. in., Mr. Keenan has been encouraged to extend his preliminary calculations of the steam table published in MECHANICAL ENGINEERING for February, 1926, to 900 deg. fahr. and 2000 lb. per sq. in. to temporarily fill the need for tables covering steam conditions in the range of high pressures and high temperatures. Mr. Keenan will tell more of his proposed work.

In the report of the Committee for 1924 I showed you some slides which gave the variation in total heat content of saturated steam and in the Mollier diagram, as reported by various authorities. In 1926 I told you of the work on steam research being conducted in England by Callendar and discussed a paper by Mr. Guy presented before the Institution of Mechanical Engineers which showed the difference between the Callendar and A.S.M.E. results. I regret to report that practically nothing of importance has appeared in either the foreign or domestic literature on the properties of steam in the past year to which I can call your attention.

Report on Progress in Steam Research at the Bureau of Standards, with a Determination of the Mechanical Equivalent of the Mean Heat Unit[1]

BY N. S. OSBORNE,[2] H. F. STIMSON,[3] AND E. F. FIOCK,[3]
WASHINGTON, D. C.

THIS report presents merely the essential results of the experiments without attempting to describe any of the details of the apparatus and method employed. These have been partially described in previous reports[4] and will be presented more completely in a later final report.

Since March 21, 1927, when the completed calorimeter was first put into actual service, experimental work on the thermal properties of water has been in progress. Actual measurements have not occupied all this time, for calibration of the apparatus itself has been a considerable part of the work, and there have been a number of operations in the nature of adjustments and modifications which are to be expected when a complicated group of apparatus is first tried out.

The first part of the work to be completed was the determination of the relation between the heat capacity of water between its normal freezing and boiling points and the electrical unit of energy. Assuming the relation between the electrical and mechanical units as known, this constitutes in effect a determination of the mechanical equivalent of heat. Briefly stated, the method employed consists in adding heat, developed and measured electrically, and distributed mechanically to a sample of water confined in a metal container so isolated from other bodies that the heat added is used to raise the temperature of the container and water sample. Initial and final temperatures are observed when liquid and vapor are in equilibrium. By measuring the heat added for both large and small samples of water, the heat capacity of a water sample is determined over the chosen range of temperature independently of a knowledge of the heat capacity of the calorimeter.

In these experiments the mass of the water samples ranged from about 250 grams to 500 grams, or roughly from about $^1/_2$ pound to one pound. The water equivalent of the calorimeter is about 210 grams.

It is possible to compute a constant for the calorimeter from the whole series of experiments between 0 deg. cent. and 100 deg. cent., permitting a value of the heat capacity of unit mass of the water sample to be computed for each separate experiment. This has been done for the purpose of showing the consistency or agreement.

The quantity thus determined is the increase in $H - L\frac{u}{u' - u}$ over the chosen temperature range. H denotes heat content of saturated liquid, L denotes heat of vaporization, and u and u' denote specific volumes of saturated liquid and vapor, respectively. $H - L\frac{u}{u' - u}$ may be denoted by α, and $L\frac{u}{u' - u}$ by β. The latter quantity may be determined calorimetrically, but at these low pressures it is small and is readily calculated from existing data. We may then compute the heat content H of saturated liquid water between 0 deg. cent. and 100 deg. cent.

The heat content, known also as "total heat" or "enthalpy," is defined as the sum of the internal energy and the pressure-volume product per unit mass.

In all, 32 complete experiments extending from near the ice point to the boiling point were made upon 11 different samples of water. These divide naturally into two groups. Fifteen experiments made between July 13 and August 10, inclusive, constitute the first group. Most of these were made in steps of ten degrees each to give the variation of the heat content of water with temperature. Seventeen experiments made between September 26 and October 29 constitute the second group. In this group each determination was made either as a single non-stop experiment or else with one or two short temperature intervals near the start for the purpose of extrapolation to the ice point.

The first group is not so concordant as the second. The crew at this time was less experienced, the character of the experiments and the climatic conditions were less favorable to accuracy, and only one of the three platinum resistance thermometers performed satisfactorily as compared to the proper behavior of all three in the second group of measurements. These fifteen earlier experiments have each been given one-fourth the weight of each of the second group of seventeen in determining the final result. Every complete experiment of this kind which was made has been included in the calculation of the mean, and none rejected on the score of discordance with the others.

Only one of the results of the last group differs from the mean by more than one part in 5000, and this one by but one part in 2000. Half of this group are within one in 10,000 of the mean. The deviation of the first group from the mean is greater, the worst result being nearly one in 1000 from the mean; however, the mean of the first group differs from the mean of the second by only one part in 9500. Careful examination of these results has failed to show any systematic dependence either on chronologic order, mass of sample, proximity of actual terminal temperatures to 0 deg. cent. and 100 deg. cent., or on any of the variations in experimental conditions which prevailed. The agreement is satisfactory and indicates that sufficient observations have been made to reduce the effect on the mean of accidental experimental errors to a practically negligible amount. Further repetitions of the experiments would not be expected to alter the mean by as much as one part in 10,000.

Corrections have been applied for all instrumental errors as well as for energy added by the circulating pump and by heat leak. The remaining error, uncorrected for because unknown, from all possible sources is estimated to be not more than one part in 5000. In other words, it is believed that the final mean value of the heat unit from these determinations is within one part in 5000 of the true value.

We find that the increase of heat content of saturated liquid water from 0 deg. cent. to 100 deg. cent. is 418.76 international joules. Applying a correction of +0.14 joule according to the latest determinations of the relation between the international and absolute units, the figure becomes 418.90 absolute joules.

The precise numerical value of the mechanical equivalent of the heat unit depends upon the definition of heat unit as well as upon the experimental data which correlate electrical or mechanical energy with energy in the form of heat. If the mean calorie is based upon measurements of heat content made at saturation pressure the value will be about 0.024 per cent or about 0.001 joule greater than if based on measurements at one atmosphere pressure. The latter has usually been chosen for defining the unit heretofore used in steam tables because calorimetric measurements on water below the normal boiling point have usually been made at atmospheric pressure. The difference is so small that it is insignificant except in calorimetry of the highest accuracy.

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[1] Publication approved by the director of the Bureau of Standards of the U. S. Department of Commerce.

[2] Physicist, Bureau of Standards.

[3] Physicist, Bureau of Standards.

[4] MECHANICAL ENGINEERING, vol. 46, no. 2, pp. 81 and 88, 1924; vol. 47, no. 2, p. 106, 1925. *Jl. Optical Soc. Am.*, vol. 8, no. 4, p. 808, 1924.

Inasmuch as the results of the work presented here offer an opportunity for considering the general adoption of a new value for the heat unit, and for the sake of securing consistency in the tabulation of the heat content of water along the saturation path, it is here recommended that the definition of the mean calorie be taken as the one-hundredth part of the change of heat content or enthalpy of one gram of saturated liquid water between 0 deg. cent. and 100 deg. cent. or in other words, the one-hundredth part of the energy which one gram of liquid water will lose in flowing continuously from a state of saturation at 100 deg. cent to a state of saturation at 0 deg. cent.

According to this definition the mechanical equivalent of the mean calorie would be

4.189 joules

and the equivalent of the corresponding mean B.t.u. would be

778.6 ft-lb.

The determination of this constant was especially urged in the commission assigned to the Bureau of Standards by the Cambridge Steam Table Conference of June, 1921. This important constant has been given first place in our experimental program, and a very great deal of time has been devoted to this particular measurement in the effort to secure the precision appropriate to the present state of laboratory technique.

The preparations for the work, however, have provided for much more extensive determinations of the thermal properties of water, and the apparatus which has served for the determination of the mechanical equivalent of the mean heat unit is designed also to determine the heat content both of saturated liquid and saturated vapor up to 300 deg. cent. and about 1200 lb per sq. in.

The measurements on saturated liquid are in progress and observations are practically completed for determination of the heat content of the liquid at every 10-deg. point from 0 deg. cent. up to 210 deg. cent. The work up to this point has yielded 224 complete determinations of heat capacity, not counting the 32 determinations of the mean calorie. The calculation of these data is not complete (Dec., 1927) but it appears that the accuracy of the results will be sufficient for all present requirements. There are also supplementary determinations to be made of the β or evaporation correction, which in this range may be determined calorimetrically.

There is yet to be undertaken a series of determinations of the heat of vaporization which will complete the measurement of the heat content of saturated steam.

Although the proposed experimental program is at present far from completed the equipment is working reliably and yielding data.

The apparatus is complicated and requires very careful handling. Very few faults have been discovered, most of which have been either corrected or overcome. No important changes either in the design or the construction have been found necessary as a result of service. No vital part has yet failed to perform its function faithfully. The supreme test will most likely come with the higher temperatures and pressures, and if the mechanical elements stand the test we may expect that the thermal performance of the apparatus will continue reliable. We believe there is excellent prospect for the completion of the projected program for the survey of the thermal behavior of steam.

Report on Progress in Steam Research at the Massachusetts Institute of Technology

By L. B. SMITH,[5] CAMBRIDGE, MASS.

I AM GLAD to report that during the past year some progress has been made on our portion of the steam-research program.

Immediately after last year's meeting, a new resistance thermometer of the strain-free type developed at the Bureau of Standards was built, calibrated, and carefully compared with the thermometer we have been using in our measurements on steam. This new thermometer is being preserved so that in the event of injury to our working standard we shall always be able to tie in our temperatures to a definite scale. The separate investigation of the absolute temperature scale under the direction of Professor Beattie of the Institute has progressed, and

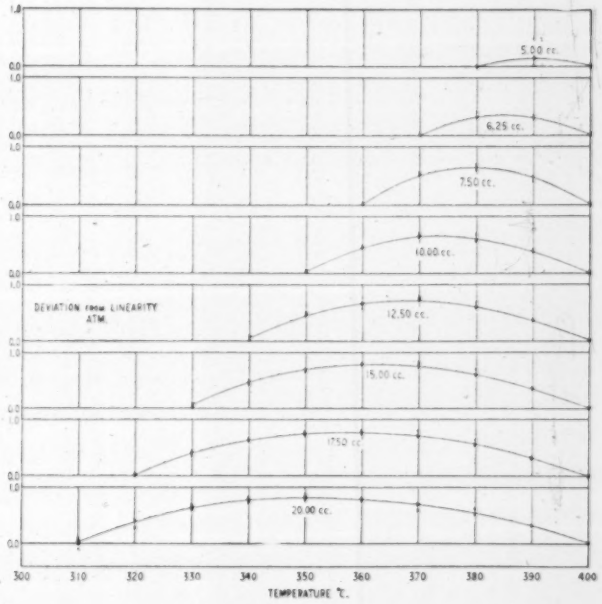


FIG. 1 METHOD USED FOR SMOOTHING THE OBSERVED PRESSURES

already about 14 resistance thermometers of various types and samples of wire have been constructed. These will be calibrated against the gas thermometers, and eventually it will be a relatively simple matter to check our instruments against them and so reduce our temperatures to the absolute scale. It will be a matter of several years, however, before this can be done.

We have recently completed the experimental determination of

[5] Research Associate, Research Laboratory of Physical Chemistry, Massachusetts Institute of Technology, Cambridge, Mass.

TABLE 1 RESULTS OF EXPERIMENTAL DETERMINATIONS ON SUPERHEATED STEAM

Temp., deg. cent.	Specific Volume, Cu. Cm. per Gram — Pressures in Atmospheres							
	5.000	6.250	7.500	10.000	12.500	15.000	17.500	20.000
310	....	....	....	....	....	....	....	92.01
320	....	....	....	....	....	....	103.80	95.75
330	....	....	....	....	....	118.01	108.17	99.40
340	....	....	....	....	135.28	123.23	112.38	102.92
350	....	....	....	156.31	141.73	128.27	116.49	106.34
360	....	....	181.18	164.72	148.06	133.20	120.50	109.70
370	....	201.79	192.95	172.90	154.13	138.00	124.42	113.00
380	225.68	215.89	204.36	180.84	160.08	142.68	128.26	116.23
390	243.19	229.66	215.47	188.61	165.91	147.28	132.01	119.40
400	260.42	243.13	226.29	196.22	171.64	151.77	135.69	122.49
No. of points	7	10	13	16	19	21	25	43
Avg. deviation, per cent	0.005	0.011	0.014	0.013	0.020	0.017	0.018	0.021

Total number of points = 154. Total average deviation = 0.017 per cent.

the *p-v-t* properties for a portion of the steam superheat region. These measurements extend from specific volumes of 20 to 5 cubic centimeters per gram and from pressures of about 92 to 260 atmospheres. The temperature range covered is from 310 deg. cent. to 400 deg. cent. The results have been computed and are presented in Table 1.

Before final values can be assigned it will be necessary to redetermine the volume of the steam container and to recompute the volume settings.

The pressure values given in the table are those obtained by a graphical smoothing of the experimental data. The average deviations are the deviations of the experimentally determined pressures from the smoothed values. The average deviations represent the reproducibility of the data rather than their absolute accuracy. The redetermination of the volume of the bomb, already referred to, may cause us to assign different values to the volumes without in any way changing the rest of the table.

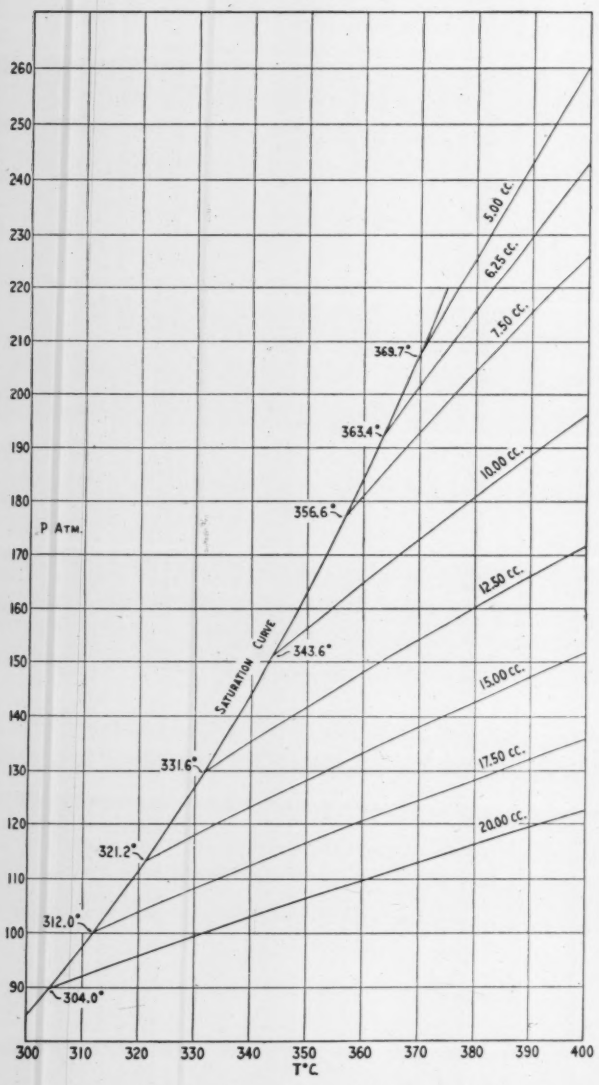


FIG. 2 ISOMETRICS AND VAPOR-PRESSURE CURVE AS DETERMINED AT THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Fig. 1 indicates the method used for smoothing the observed pressures. For each constant volume two points were arbitrarily chosen and an equation representing pressures as a linear function of the temperature was passed through them. Deviations of the actually observed pressures from the calculated ones are plotted against the temperatures and the best smooth curve passed through the points. The smoothed deviations are read from the curves. It is interesting to note, and I think fairly obvious from the diagram, that the curvature of the isometrics is less as the temperature becomes higher. This fact coincides with our ideas of molecular association or aggregation in vapors.

Fig. 2 represents the isometrics together with the vapor-pressure curve as determined at the Institute. The intersections of the isometrics with the vapor-pressure curve give the saturated specific volumes of the vapor; or, more specifically, the temperature at which a given constant volume line intersects the saturation curve is the temperature at which that volume is the saturation volume.

It may be argued that we are not justified in an extrapolation of the isometrics to the saturation line, but that a change in the form of the curves takes place as the saturation condition is approached. This is an extremely difficult matter to decide experimentally, but from our own work we have nothing to indicate that such is the case.

By the adiabatic expansion of superheated vapor in the absence of dust and ionized particles, Coulier[6] has actually realized an unstable state of supersaturation without any abrupt changes taking place in the system. This would seem to indicate that abrupt changes are not to be expected before the saturated condition is reached. For many substances, on the liquid side, it is possible to pass the saturation condition and maintain the liquid in a superheated state. This has been noted particularly in the case of anhydrous ammonia, where it is said that the crossing of the saturation line takes place without abrupt changes.[7]

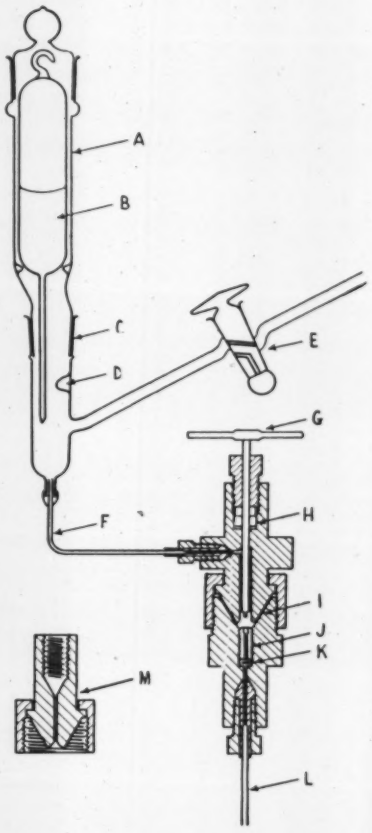


FIG. 3 DIAGRAM OF APPARATUS TO BE USED IN LOADING WATER INTO THE BOMB AND DEVICE FOR LOCKING A LOADING IN PLACE

The accuracy of our assumption can be tested as soon as the Bureau of Standards provides us with latent-heat values. By means of the Clapeyron equation we can calculate saturated-vapor volumes from the latent heat, the saturated-liquid volumes, and the rate of change of pressure with temperature along the saturation curve.

[6] Coulier, *J. Pharm. Chim.*, (4) 22 (1875), pp. 165 and 254.

[7] Private communication from Dr. James A. Beattie of the Massachusetts Institute of Technology.

At the present time we are getting ready to extend our measurements to larger specific volumes. The new steam containers that were described last year have been welded up and are now ready for calibration.

The loading apparatus has been constructed and a considerable number of samples of water have been purified and are ready for loading.

Fig. 3 is a diagram of the apparatus to be used in loading the water into the bomb and the device for locking a loading in place.

The glass portion at the upper left of the diagram consists of a tube *A* having a ground joint *C* at its lower end. The tube *B* holds a weighed sample of pure, air-free water and has a long tip extending below the ground joint. It will be noted that the neck of the tube *A* is slightly offset just above the ground joint. By rotating the ground joint the long tip of tube *B* comes in contact with the projection *D* and is broken off. This releases the water and permits it to pass through the metal connections and finally into the bomb through the tube *L*. Before releasing the water the whole system including the bomb is completely evacuated through the stopcock *E*, which is then closed. After the water is released, the bomb is cooled with liquid air and sufficient time is allowed for the last traces of water to collect in the bomb. Now, by means of the screwdriver *G*, working through the packing *H*, the small plug *V* is screwed down tightly upon the gold disk *K*. This operation effectively seals the passage and confines the entire charge of water within the bomb. The cone joint *I* is now opened and the screwdriver portion replaced by the part *M*. This is connected by means of a steel capillary tube with the mercury injector and pressure gage. The connecting tubes are now evacuated and mercury introduced to fill everything up to the gold disk.

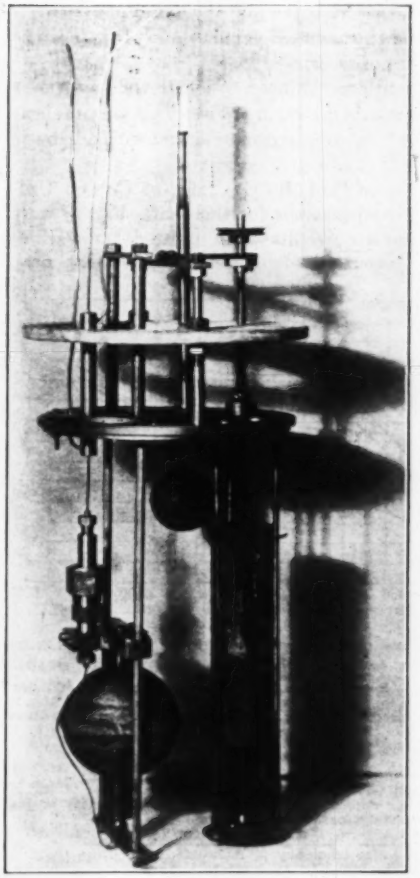


FIG. 4 ONE OF THE NEW STEAM CONTAINERS AND METHOD OF SUPPORTING IT IN THE HIGH-TEMPERATURE BATH

The setting of the mercury injector is next taken under different pressures and everything is ready for communication to be established with the bomb. The bomb and the connector are introduced into the high-temperature bath and a high pressure is exerted by the mercury upon the gold disk. Under these conditions the mercury quickly amalgamates the gold and effects contact with the steam in the bomb. Everything is now ready for a series of *p-v-t* measurements.

Fig. 4 shows one of the new steam containers and the method of supporting it in the high-temperature bath. The coupling containing the gold disk may be seen just above the bomb. To the right is the bath stirrer and in the rear may be seen the float for indicating the level of the bath liquid. The thermometer, heater, and temperature-regulating element are not shown. It will be noted that the steel capillary tube emerging from the bath is provided with a water jacket. This enables us to maintain the mercury in the communicating tube at a known temperature over the greater portion of its length. The gradient from the bath temperature to the temperature of the cooler is made to occur in as short a distance as possible in order that volume errors at this point may be small and easily estimated.

Much of the time now consumed in making a loading of water should be saved by the use of the new method. It will be possible to bake out and evacuate one of the bombs and load water into it while measurements are being made with the other bomb. Only a comparatively short time will be required to shift bombs and get the necessary zero setting for the new series.

As a check on the measurements already made, it is planned to overlap as much of that field as possible with the new apparatus.

Report on Reheat Factors

BY E. L. ROBINSON,[8] SCHENECTADY, N. Y.

A CHART of reheat factors suitable for calculations on condensing or non-condensing steam turbines has been prepared, the basis of which is the steam data compiled by the General Electric Company for the A.S.M.E. Committee on Steam Research.[9]

The following remarks outline the method of computation. The reheat factors given are for a steam expansion at a uniform stage efficiency of 80 per cent and an infinite number of stages. Simple rules given on the face of the diagram enable the correction of the scaled value for any other efficiency or any particular number of stages. More accurate diagrams which these rules represent approximately are given in an article in the *General Electric Review* for July, 1926.[10] That article published charts of reheat factors for expansion to 1 in. Hg absolute back pressure, computed graphically from Goodenough's total-heat–entropy diagram.

The reheat factors for the new steam chart have been worked out by a process of computation devised to utilize all the accuracy of the large-scale diagram. The first requisite was a series of condition curves at 80 per cent uniform stage efficiency. The scheme of calculating these curves is based on a suggestion by Mr. J. H. Keenan to assume the change of temperature along the condition curve proportional to change of total heat. This assumption proves entirely satisfactory in the superheated region, but in the wet region the step used in calculation must be limited in length or accompanied by a correction factor.

The fundamental assumption is this: Along the curve,

$$\frac{dT}{dH} = \frac{\Delta T}{\Delta H}$$

for a complete step. From the principles of the thermodynamics

[8] Turbine Engineering Department, General Electric Company. Mem. A.S.M.E.

[9] Progress Report on Development of Steam Charts and Tables from the Harvard Throttling Experiments, by J. H. Keenan. MECHANICAL ENGINEERING, February, 1926, p. 144.

[10] Notes on the Comparison of Steam Turbine Efficiencies, by E L. Robinson. *General Electric Review*, July, 1926.

$$dN = \frac{1 - e}{e} \frac{dH}{T}$$

so that according to the assumption

$$dN = \frac{1 - e}{e} \frac{\Delta H}{\Delta T} \frac{dT}{T}$$

$$\Delta N = \frac{1 - e}{e} \frac{\Delta H}{\Delta T} \log_e \frac{T_1}{T_2}$$

where T = absolute temperature
H = total heat
N = entropy, and
e = stage efficiency.

The scheme of calculation is to choose a starting point represented by an initial entropy, total heat, and corresponding temperature. A convenient lower temperature is then selected and the corresponding final entropy and total heat at the selected lower temperature are calculated as follows:

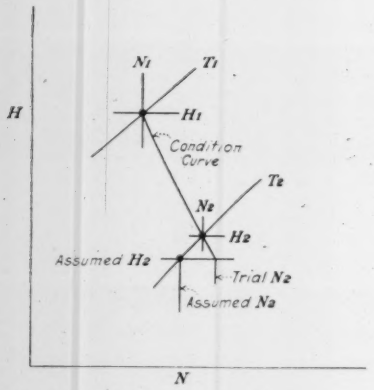


FIG. 5 MANNER OF ADJUSTMENT

The temperature ratio T_1/T_2 is fixed for the step of expansion. At the lower temperature an approximate total heat is estimated and the corresponding entropy noted. From the estimated assumed heat drop the formula gives a trial increase of entropy at the assumed final total heat, but it will not come at the assumed temperature.

$$\text{Trial } \Delta N = \left(\frac{1 - e}{e}\right) \times \frac{\text{Assumed } \Delta H}{\Delta T} \times \log_e \frac{T_1}{T_2}$$

Fig. 5 illustrates the manner of adjustment. The slope of the final temperature line is noted. In the wet region this is the absolute temperature itself, and in the superheated region it is so small as to be almost negligible with good trial assumptions. It is positive. The slope of the condition curve is

$$\frac{\Delta H}{\Delta N} = \frac{e \Delta T}{(1 - e) \log_e \frac{T_1}{T_2}}$$

and the numerical value is negative.

The entropy correction, to be added algebraically to the trial N_2, is given by a solution of the small triangle whose base is the difference between the assumed and the trial N_2.

Entropy Correction

$$= N_2 - \text{trial } N_2$$

$$= \frac{(\text{Ass. } N_2 - \text{Trial } N_2) \text{ Slope of temp. line}}{\text{Slope of temp. line} - \text{Slope of condition curve}}$$

Only a reasonably good initial guess is required, so that this correction will not need to be recalculated by a second trial (in spite of the fact that chord slope is used instead of the tangent of the condition curve).

At this point of the computation, if in the wet region cognizance is taken of the deviation of true temperature variation from the assumed rule of proportionality, a "step correction" is added to the computed final entropy.

Actual heat drop, B.t.u.	Entropy correction per step
50	0.00001
100	0.00005
150	0.00020
200	0.00045

These corrections were prepared by comparing calculations made with very small steps with similar calculations based on large steps. The correction varies slightly at large and small entropies but this need not be considered, and in fact with steps of less than 100 B.t.u. the correction is hardly needed at all.

The correction for the assumed final total heat is the product of the slope of the temperature curve and the difference between the final value of N_2 and the assumed value of N_2. It is positive if (N_2 — Assumed N_2) is positive.

The aim of the calculations has been to locate the final point of the condition curve within 0.1 B.t.u. From this curve reheat factors are quickly found by comparison of actual with adiabatic heat drops.

Especial credit is due to Prof. R. E. Clark, of Cornell University, by whom the computations for the chart, Fig. 6, were carried out. The complete results were plotted for various initial pressures and superheats against adiabatic heat drop

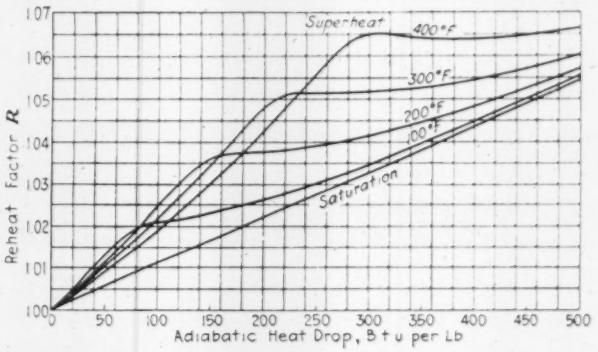


FIG. 6 REHEAT FACTORS R FOR VARIOUS ADIABATIC HEAT DROPS FOR STEAM EXPANSION WITH AN INFINITE NUMBER OF STAGES (Constant stage efficiency, 80 per cent; initial superheats, 0 to 400 deg. fahr.; closely approximate for initial pressures from 20 lb. per sq. in. abs. to 700 lb. per sq. in. abs. Based on Chart in Feb., 1926, issue of MECHANICAL ENGINEERING.)

NOTES

1 With any particular number of stages the heat recovery $(R-1)$ is decreased by a fraction nearly equal to the reciprocal of the number of stages.

2 With any other stage efficiency the heat recovery is greater or less nearly in proportion as the stage loss is greater or less.

$$\text{Reheat factor} = \frac{\text{Actual heat drop}}{\text{Stage efficiency} \times \text{Adiabatic heat drop}}$$

and also against pressure ratio during expansion. The adiabatic-heat-drop base gives Fig. 6, for which the variation of reheat factor with pressure at any particular superheat is so small that it may ordinarily be safely neglected in turbine computations.

Report on Proposed High-Pressure-Steam Chart Development

BY J. H. KEENAN,[11] SCHENECTADY, N. Y.

TWO years ago the General Electric Company presented to the A.S.M.E. Committee on the Properties of Steam, its work on the development of steam charts and tables extending to a maximum pressure of 1200 lb. per sq. in. and a maximum temperature of 800 deg. fahr. These data were based primarily on the Davis-Kleinschmidt Joule-Thomson coefficients which

[11] Turbine Engineer, General Electric Company, Jun. A.S.M.E.

reached a maximum pressure of 565 lb. per sq. in. abs. and a maximum temperature of 657 deg. fahr.

Early in November of this year (1927), Dr. L. B. Smith, of the Massachusetts Institute of Technology, made available to us the results of a series of experimental determinations of specific volumes that have recently been completed as part of the A.S.M.E. Steam Research Program. They extend from 1325 lb. per sq. in. to 3827 lb. per sq. in. and from 590 deg. fahr. to 752 deg. fahr. (Fig. 7).

TABLE 2 COMPARISON OF STEAM TABLES AT HIGH PRESSURES

	Marks and Davis	Stodola	Callendar	Knoblauch	Goodenough	A.S.M.E. chart
Upper limit of table (lb. per sq. in.)	600	1442	2000	850	800	1200
Means of extrapolation	graphic	...	...	graphic	formula	...
SPECIFIC VOLUME (cu. ft. per lb.):						
1000 lb. per sq. in. abs., 750 deg. fahr.	...	0.654	0.677	0.625	0.659	0.648
500 lb. per sq. in. abs., 725 deg. fahr.	1.402	1.346	1.362	1.318	1.356	1.340

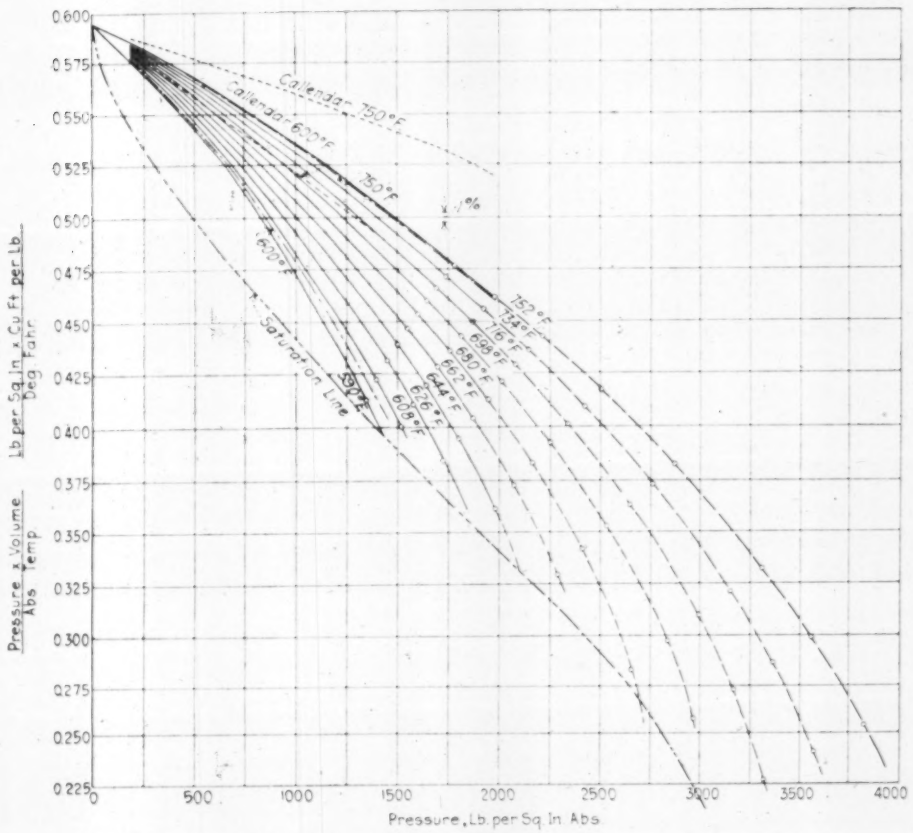


FIG. 7 PRESSURE-VOLUME-TEMPERATURE RELATIONSHIP FOR SUPERHEATED STEAM

[Curves below 1200 lb. per sq. in. from A.S.M.E. Steam Tables (MECHANICAL ENGINEERING, Feb., 1926); encircled points obtained from Dr. L. B. Smith (M.I.T. specific-volume determinations for A.S.M.E. Steam Research Program).]

Naturally, our first move on receiving the new data was to compare them with the A.S.M.E. Table of Specific Volumes.[12] For convenience the product pV/T was plotted against pressure along constant-temperature lines (Fig. 7) and also against temperature along constant-pressure lines (Fig. 8). It was found that the lines shown in Figs. 7 and 8 represented adequately the new data and the A.S.M.E. table. The plotted points show the extent to which individual values from each set of data differ from the line values.

The close agreement between the new data and the A.S.M.E. table is quite remarkable considering the fact that the only experimentally determined specific volumes available at the time the table was calculated extended to no higher pressure than 160 lb. per sq. in.

As shown by Table 2 (which is reprinted from p. 151, MECHANICAL ENGINEERING, February, 1926), the A.S.M.E. table gives the lowest specific volumes of all the well-known tables with the exception of that of Knoblauch, while the Callendar table gives the highest. To show the upper limit of the values given by the various tables, two isotherms from the Callendar table are given in Fig. 7.

The new volume determinations appear to justify the A.S.M.E. specific-volume table, particularly at pressures below 1000 lb. per sq. in., and offer a basis for calculating a new steam chart for pressures above 1000 lb. per sq. in. Our present intention is to use the curves of Figs. 7 and 8 as the basis for steam tables and charts giving the properties of steam from 750 lb. per sq. in. to the critical pressure and from the saturation line to 900 deg. fahr.

The total heats and entropies at pressures above 750 lb. per sq. in. and temperatures up to 800 deg. fahr. will be found by graphic differentiation of the lines of Fig. 8 followed by an integration of the following derivatives:

$$\left(\frac{\partial \phi}{\partial p}\right)_T = -\left(\frac{\partial V}{\partial T}\right)_p$$

$$\left(\frac{\partial H}{\partial p}\right)_T = -\frac{T^2}{p}\frac{\partial}{\partial T}\left(\frac{pV}{T}\right)_p$$

The A.S.M.E. 750-lb. per sq. in Mollier diagram will not be altered, but the 1200-lb. per sq. in. extrapolation will be completely recalculated.[13]

The volumes at temperatures above 752 deg. fahr. are to be obtained from the purely graphic extrapolation shown in Fig. 8. The method of obtaining total heats and entropies at temperatures above 800 deg. fahr., the highest temperature on the A.S.M.E. Mollier diagram, has not been definitely determined on, but the probable procedure will be an extrapolation of the adiabatic exponent $\gamma = \log \frac{P_1}{P_2} + \log \frac{V_2}{V_1}$ to the required temperature at some one entropy and determining the total-heat rise at constant entropy from a point of known total heat to the high temperature point from the equation:

$$\Delta H = \frac{1}{J} P_1 V_1 \frac{\gamma}{\gamma - 1}\left[1 - \left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}}\right]$$

This method has the advantage of yielding percentage errors in ΔH that are only $^1/_5$ the percentage error in γ. Only one point at any temperature need be determined by this method, the remainder being obtained in the same manner as the lower temperature values.

[12] MECHANICAL ENGINEERING, February, 1926, p. 147.

[13] MECHANICAL ENGINEERING, February, 1926, p. 150.

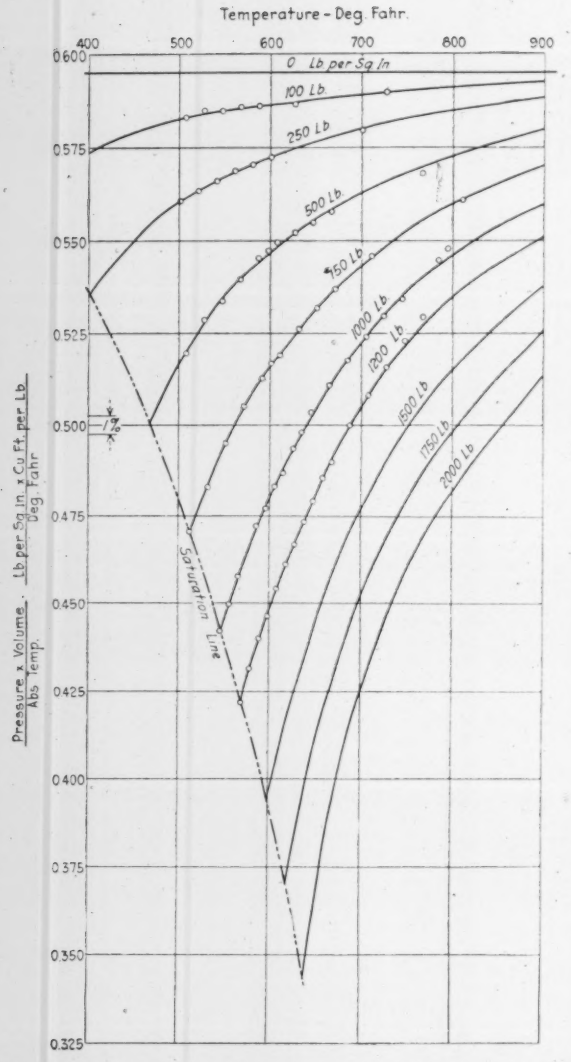


FIG. 8 PRESSURE-VOLUME-TEMPERATURE RELATIONSHIP FOR SUPERHEATED STEAM

[Encircled points taken from A.S.M.E. Steam Table (MECHANICAL ENGINEERING, Feb., 1926); higher pressure lines based on data obtained from Dr. L. B. Smith (M.I.T. specific-volume determinations for A.S.M.E. Steam Research Program).]

Steam Research

BY HARVEY N. DAVIS[14]

TODAY'S steam-research session has been indeed a notable one. We have had presented to us dependable experimental data on water and steam in such quantity and of such quality as to put our research project beside those of Professor Knoblauch's laboratory in Munich and the Reichsanstalt in Berlin as the most considerable contributions to the subject since Regnault.

In the general field of steam research the most interesting items of news are: (1) that Professor Knoblauch has under way a new series of specific-heat measurements at pressures up to 1500 lb., which are to be published in the near future; (2) that Dr. Jakob in Berlin is measuring the latent heat of steam at temperatures higher than those reached in Henning's earlier work at the Reichsanstalt (two preliminary values are reported on page 720, *Z.V.D.I.*, May 21, 1927); and (3) that a commission appointed by the Masaryk Academy of Work in Prague is experimenting with steam at 500 deg. cent. (932 deg. fahr.) at pressures up to 250 atmospheres (3675 lb. per sq. in.), some of the results being now ready for publication.

At Harvard we have revised and correlated our heat-leak corrections for our 41 points. We have also devised a more satisfactory formulation of μ for interpolation, and particularly extrapolation.

From work on other substances we know that the Joule-Thomson coefficient at low pressures should be positive at ordinary temperatures, should go through zero at an inversion point the temperature of which is probably between 5 and 8 times the critical temperature, and should be negative at all higher temperatures. We know also that at any temperature below the inversion temperature, μ should be positive at low pressures and negative at high pressures. Above the inversion temperature, μ should be negative at all pressures however great. The new formulation has been adjusted so as to meet all these requirements, including giving an inversion point at about 6 times the critical temperature. We have therefore more confidence in extrapolation of the new formulation, particularly to temperatures above the experimental range, than with the formulation used by Mr. Keenan and myself two years ago, at which time these various qualitative checks were not so carefully attended to.

The new formulation is also better than our previous one in that our constant-temperature lines on the μ vs. p plot are no longer parabolas, but now take into account a variation of curvature with pressure which seems to be established by our last year of experimental work.

The average of the algebraic deviations of our 41 points from the new formulation is less than $^1/_{50}$ of one per cent, and when the deviations are classified into groups on either a pressure or a temperature basis, there seems to be no systematic trend.

The average of the deviations without regard to sign is just under 1 per cent, the larger deviations (of both signs) occurring at low pressures and low temperatures, where they are of least importance in connection with the desired extrapolations.

We are now engaged in integrating the formulated μ's to get lines of constant total heat, and in computing from these results a new specific-heat-ratio chart, as explained two years ago by Mr. Keenan. In these laborious processes the Turbine Engineering Department of General Electric Co. at Schenectady is again giving effective and much appreciated assistance. We hope that it will not be long before we are in a position to check and perhaps improve the provisional Mollier diagram presented by Mr. Keenan two years ago.

THE Polytechnic Institute of Brooklyn, through its Faculty and Corporation, has voted to raise the standard of its engineering degrees by increasing the requirements for these degrees. Under the new plan, which becomes operative with the class of 1932 which enters next September, the degrees of Bachelor of Civil, Electrical, and Mechanical Engineering will be granted at the end of the regular four-year course. The Bachelor of Chemical Engineering will be granted at the end of a five-year course. Then upon the completion of one year of actual experience in the engineering field and upon completion of twelve semester hours of graduate evening work at the Institute, the degree of Civil, Electrical, Mechanical, or Chemical Engineer will be granted. Or, the engineering degree may also be gained by three years of approved engineering experience and the submission of a thesis. The granting of engineering degrees for men of the evening courses will be governed by similar requirements as those of the day courses, though here the engineering experience may be concurrent.

[14] Professor of Mechanical Engineering, Harvard University, Cambridge, Mass. Mem. A.S.M.E.

SURVEY OF ENGINEERING PROGRESS

A Review of Attainment in Mechanical Engineering and Related Fields

The Reciprocating Steam Engine as a Modern Prime Mover

THE SUPERIORITY of the steam turbine as compared to the reciprocating steam engine in the way of weight per unit of output and the superiority of the internal-combustion engine as regards fuel consumption and ability to start quickly have considerably restricted the field of application of the reciprocating steam engine but have not killed it entirely. The fact that the reciprocating engine has not disappeared completely is startling and well worth consideration. The main reason why it continues to exist is that it uses high-pressure steam which is excellently adapted after it has done work in the engine to be used for heating purposes. The trend of development of the steam engine during the last few years has been radically different from what it was before the war. In one respect only has there been no change, and that is that every effort has been directed toward increasing reliability and to simultaneously simplifying attendance. The matter of reliability has become particularly important of late, since with the present system of interlocking power and heat generation, even a small interruption of operation would cost more than any possible saving for weeks at a time.

Because of this, complicated valve gears and governing devices have been rapidly giving way to a few simple and reliable designs. This is true also in the field of lubrication, which has been made as automatic as possible by the introduction of lubricators, pressure oil lubrication, etc. until on a modern steam engine not a single part has to be oiled by hand.

The World War brought about a revolutionary change in the conception of economic operation of a steam engine. There was, of course, a consistent effort at all times even before the war to make the operation as economical as possible, but an engine was then considered as being economical as long as its steam consumption was low. Since the war, shortage of capital and fuel have brought about a radical change in attitude toward this question. [The author deals primarily, of course, with German conditions.—EDITOR.] It is now recognized that steam consumption is not the only factor affecting the economy of an engine, but that the number of revolutions has also to be taken into consideration since this affects the weight and hence the amount of material put into the engine, the cost of its construction and transportation, and finally the interest and depreciation account; furthermore, a higher speed of rotation means smaller foundations, reduced floor space, and cheaper buildings. All of these considerations lead to a tendency to increase the rotative speeds of a steam engine. A broader view of the idea of steam consumption itself began to appear lately through the recognition that high steam consumption means not only an increase in cost of coal in what might be called dollars and cents, but also waste of coal, which is an important asset of natural wealth. This led to a determined effort to improve the utilization of the heat content in coal through an increase of pressure and the superheating of steam, reduction of heat losses in the engine itself, and recovery of heat from flue gases. The condenser was recognized as a "devourer" of heat in which from 50 to 60 per cent of the heat in the fuel is senselessly destroyed, in just the same way as formerly the top gases from a blast furnace were allowed to go up in flame uselessly. An idea grew up that power generation is closely allied with heat generation and that the steam engine must be made an integral member of the power and heating system of a plant. When this was recognized it was found that the reciprocating engine is usually well suited for such an arrangement, and it is these views which have become the driving force in the modern development of this type of engine. From this point of view it becomes necessary to discuss briefly the range within which the reciprocating steam engine is capable of competing with such other power generators as the internal-combustion engine and the steam turbine. No reference is here made to hydraulic and wind-power plants, as their use is confined to certain localities only. [Attention is called to the author's inclusion of wind-power plants in this discussion; no one in America would probably do so.—EDITOR.]

LIMITATIONS ON THE EMPLOYMENT OF THE RECIPROCATING ENGINE

The internal-combustion engine can be started on very short notice, and when not in operation consumes no fuel. It is also superior to the steam engine in its degree of fuel utilization, its efficiency being about 36 per cent as compared to 13 per cent for the steam engine. This superiority exists, however, only when both types are considered as pure power generators. If a given concern requires substantial amounts of heat and has no by-product gases that could be burned in an internal-combustion engine, the steam engine begins to show its superiority. The exhaust gases from an internal-combustion engine are not as suitable for heating purposes as steam, as they cannot be cooled very much on account of the danger of formation of corrosive acids. On the other hand, the exhaust from a steam engine condenses after leaving the latter at temperatures economically suitable for purposes of heating, and in condensing releases enormous amounts of heat without very great change in temperature. This circumstance makes exhaust steam eminently suitable for cooking, heating, evaporation, and the preparation of hot water.

A further disadvantage of the internal-combustion engine is that it can be overloaded only to a small extent, while the steam engine will stand an overload up to 100 per cent or even more. The result is that in the case of a steam engine the output within a wide range is independent of the speed of rotation, which makes of the steam engine a constant-output and of the internal-combustion engine a constant-torque machine. The steam engine is therefore particularly appropriate for operations where there are considerable variations in power demand, while the internal-combustion engine can work under these conditions only through the intermediary of mechanical, hydraulic, or electric transmissions.

In a steam turbine the pressure of the steam is converted into velocity and the flow energy is delivered to the rotor blades. The power output here is obtained by small forces working at high velocities, the result of which is that a turbine operates at high speeds and hence has smaller dimensions and weight and requires lighter foundations and less floor space. In a steam

engine the pressure of the steam acts on the piston directly. As a crank drive can run only at comparatively low speeds the first cost and cost of installation are higher than in the case of the turbine. On the other hand, however, the turbine has a low thermodynamic efficiency in the high-pressure range, due to the fact that with steam at high pressure and hence small specific volume, the blades have to be short and the clearance losses great; on the other hand, the reciprocating engine operates over this range at a high thermodynamic efficiency. In the low-pressure part the efficiency of the turbine is excellent, because of the long blades and comparatively small clearance losses, while the efficiency of the steam engine is poor as it is impossible to remove quickly low-pressure steam with its enormous specific volume. This is the reason why there is an advantage in replacing the steam engine by a turbine in the low-pressure range, as has been done for use on shipboard in the Bauer-Wach system (described in MECHANICAL ENGINEERING, vol. 49, no. 6, June, 1927, p. 686).

It follows from this also that a steam engine has to be designed for a given back pressure, while the blading of the steam turbine has to be selected to handle a given volume of steam at a predetermined velocity. As a further consequence the efficiency of the steam turbine falls off not only with a change in load, but also with a change in the volume of steam (bleeding) and the number of revolutions. In the case of a steam engine the steam consumption varies only slightly with a varying supply of steam to the cylinder.

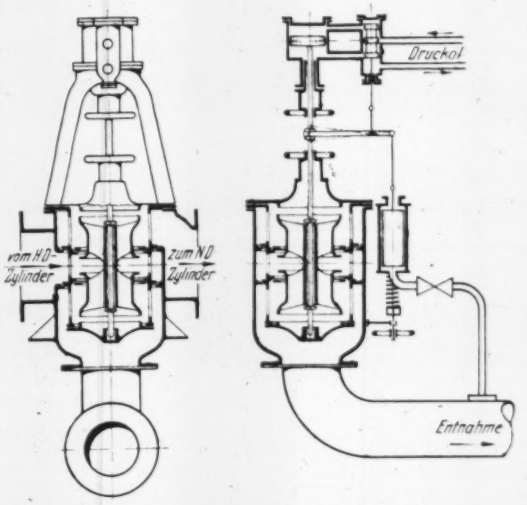
The ability of the reciprocating engine to compete with the steam turbine is the greater the more nearly the uneconomical low-pressure range is eliminated. When working with pure condensation the steam turbine is superior to the reciprocating engine beginning with outputs of around 800 hp. Higher horsepower outputs must be considered, however, when because of bleeding the low-pressure cylinders give a smaller output, and the situation is still less favorable for the turbine where the low-pressure cylinder is completely eliminated. In such cases it is only at outputs of around 1500 hp. that the superiority of the steam turbine begins to assert itself, and there are instances where even at 2000 hp. the reciprocating engine is found to be more economical because its lower consumption of steam compensates for its higher first cost and cost of installation.

At outputs in excess of 2000 hp., at least in stationary as compared with marine installations, the turbine is decidedly superior to the reciprocating engine, because at those outputs the lower speed of the engine begins to affect unfavorably the cost of the electrical part of the installation. In installations on shipboard the limit in favor of the reciprocating engine rises to 3000 and even up to 4000 hp., because here the electrical part need not be taken into consideration, and also because the turbine efficiency in the low-pressure range is comparatively low on account of the unsatisfactory vacuum that may be secured with the comparatively warm sea water in the condensers.

INCREASING THE ECONOMY OF THE RECIPROCATING STEAM ENGINE

The development of the steam engine since the war has been in the direction of increasing its thermal efficiency to make it possible for it to compete with the internal-combustion engine. This has been done by raising the pressure and temperature of the steam and by improving the working cycle so as to reduce losses; a strenuous effort has also been made to take advantage of the adaptability of the reciprocating steam engine to variable power and heat demands; finally, an effort has been made to reduce the cost of construction of the engine so as to make it possible for it to compete with the steam turbine. The other developments connected with the employment of the higher steam pressures have been reduction of losses by interstage heating, reduction of clearance space by employment of high-lift plate valves, etc. All of these developments are still in the evolutionary stage, and further progress may be expected.

The main effort of steam-engine designers at present lies in the direction of adapting the engine as much as possible to the requirements of combined power and heat generation. In this connection an effort is made to reduce as much as possible losses from the boilers, flue gases, the engine itself, and the piping; not to permit any heat to escape into the condenser or atmosphere; to operate only high-pressure boilers; not to lose the high pressure in throttling valves, but to use it up in reciprocating engines; to use for purposes of heating only the lowest possible pressures, and where the demand for heat varies greatly to use as little live steam as possible and get along without steam or heat storage. The main aim of the present designer is to do away as far as possible with the condenser and exhaust into free atmosphere.



FIGS. 1 AND 2 EXTRACTION GOVERNOR BUILT BY WUMAG AT GÖRLITZ

(*vom H D zylinder* = from the high-pressure cylinder; *zum N D zylinder* = to low-pressure cylinder; *druckol* = oil under pressure; *entnahme* = bleeding.)

The greatest difficulty in achieving this purpose arises from the wide variation in the demand for power and heat in many concerns employing steam engines.

In reciprocating steam engines with interstage bleeding, the steam line is branched off from the receiver. Therefore only a part of the steam supplied to the engine is permitted to work in the low-pressure cylinder, and the regulation of the steam bled is effected by varying the output of the low-pressure cylinder, the pressure variations in the bleeder line bringing about this regulation, which can be either by throttling or by cut-off.

Figs. 1 and 2 show an extraction governor of the first type (the Wumag). A throttle valve operated by a servomotor of the oil-pressure type is located between the pipe leading from the high-pressure to the low-pressure cylinder on one hand and the place where the steam is taken off. The valve controls the flow of steam from the high-pressure cylinder into the low-pressure cylinder or into the outside bleeder system. The valve is so set that in one extreme position it delivers only just enough steam into the low-pressure cylinder so that it will not run dry, and allows the rest to flow into the outside system, while in the other extreme position all of the steam goes into the low-pressure cylinder and the outside steam piping is cut off completely. By this means the output of the engine can be

regulated from full load to about half-load, it being assumed that the output at full load is equally distributed between the high-pressure and the low-pressure cylinders. The steam delivered into the outside system can be varied from zero to about 100 per cent of the amount supplied to the engine. This method of governing is not an ideal one since, because of its presence, the low-pressure cylinder is working practically all the time with throttled steam, which means losses. It is therefore used chiefly where it is not desired to change completely the low-pressure-cylinder valve gear. On the other hand, however, this arrangement has the advantage that it is easy to install and permits converting any ordinary steam engine into an extraction engine in a very short time.

Far more economical are methods of control wherein the variation in bleeder steam pressure controls the low-pressure-cylinder valve gear, by varying its cut-off, which can be made from about 5 per cent (which is sufficient to prevent the cylinder from running empty) to the maximum of 70 per cent. Fig. 3 shows a direct-acting regulator of this kind, built by A. Borsig. The receiver steam goes over a plunger piston *a* into the pressure cylinder *b* connected with the admission control gear of the low-pressure cylinder. The counter force is provided by two springs *c*. Pressure variations in the bleeder line therefore exert forces producing changes in admission to the low-pressure cylinder. This arrangement is suitable, however, only for valve gears which do not require much force to operate. For other gears one has to use some such servomotor arrangement as that shown in Fig. 4. The bleeder steam acts here on the oil valve *a*, which admits oil under pressure into cylinder *b*, which in its turn changes the adjustment of the low-pressure-cylinder valve gear. The same purpose can be achieved electrically, and the original article shows a device of that character built by the Hanomag organization.

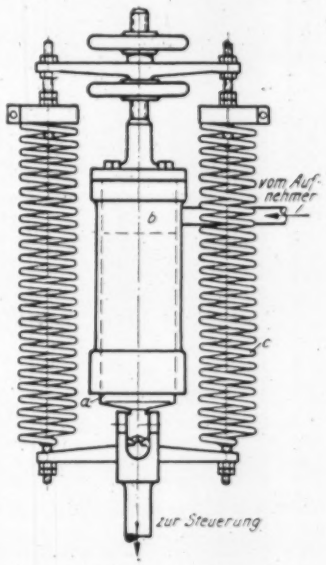


FIG. 3 DIRECT-ACTING EXTRACTION GOVERNOR CONTROLLING THE CUT-OFF IN THE LOW-PRESSURE CYLINDER (BUILT BY A. BORZIG, BERLIN-TEGEL)

(*a*, plunger piston; *b*, pressure cylinder; *c*, counterpoise springs; *von aufnehmer*, from receiver; *zur steuerung*, to valve gear.)

Fundamentally all interstage bleeder engines suffer from a defect, namely, that a part of the steam always escapes into the condenser, which is due to the fact that the low-pressure cylinder cannot be allowed to run completely empty. Furthermore, at full interstage bleeding the engine cannot deliver more than about half of its power, while no steam can be supplied to the outside system when the load is such as to require the machine to run at full output. Engine output and available volume of extraction steam are therefore in competition, while conditions of operation of the plant may require both to increase or decrease simultaneously.

To meet this condition resort is made to the single-stage machine with extraction steam. This type has gained considerably in public favor recently, as it uses for heating purposes only steam of the lowest possible pressure and utilizes the pressure difference as much as possible for purposes of power generation. Furthermore, with increase in superheat the compounding action becomes less and less important, as most of the steam leaves the engine while still dry.

Several arrangements are available for engines with steam extraction. The simplest can be used when more extraction steam is regularly used than would be produced considering the power consumption of the plant. In this case the engine works

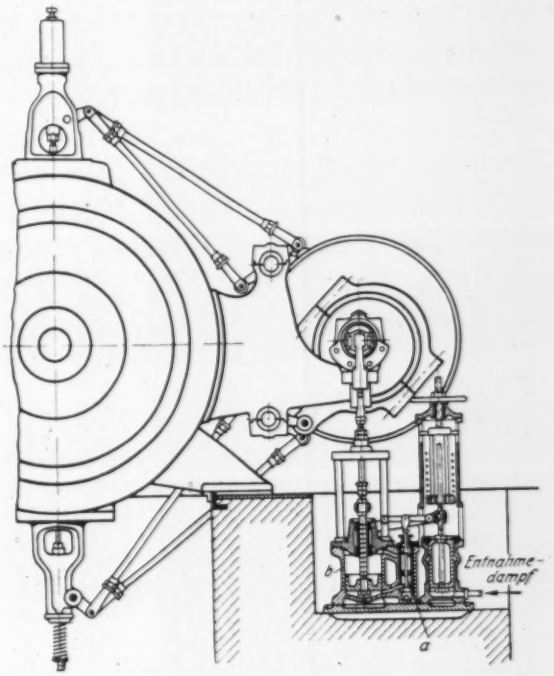


FIG. 4 EXTRACTION GOVERNOR WITH CUT-OFF REGULATION AND SERVOMOTOR BUILT BY WUMAG

(*a*, oil valve; *b*, pressure-oil cylinder; *entnahme dampf*, bleeder steam.)

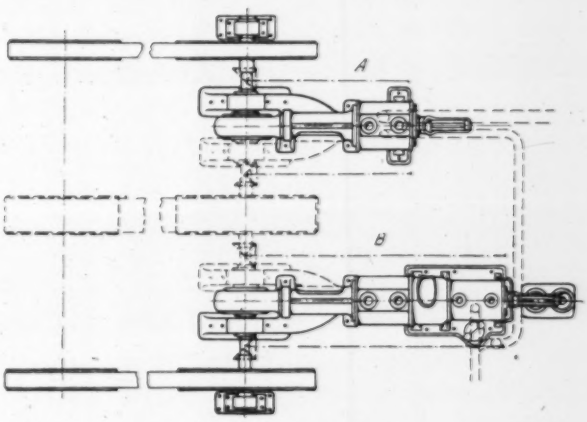


FIG. 5 EXTRACTION SYSTEM WITH TWO COUPLED STEAM ENGINES

as a pure back-pressure machine, which means that the entire exhaust goes into the heating system.

In another case there may be two engines connected either mechanically (through crankshaft or transmission) or electrically (generator or network). In Fig. 5 engine *A* is a single-cylinder unit, the output of which varies through change in cut-off in accordance with the demand for exhaust steam, all of the steam going into the exhaust piping. *B* is a compound condensing engine, and its purpose is to provide for the excess output over and above what engine *A* can do. Variations in power demand

are taken care of by its governor. This can also be a single-cylinder machine working condensing, or where the basic demand for exhaust steam is large, as a back-pressure unit. Careful attention must be paid so that the engines will not get into trouble if more exhaust steam is demanded than corresponds

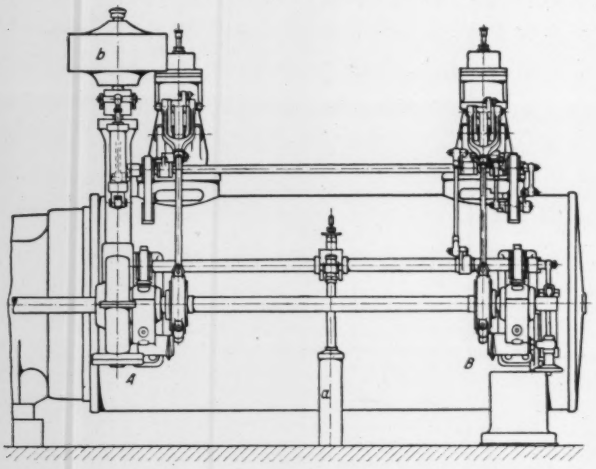


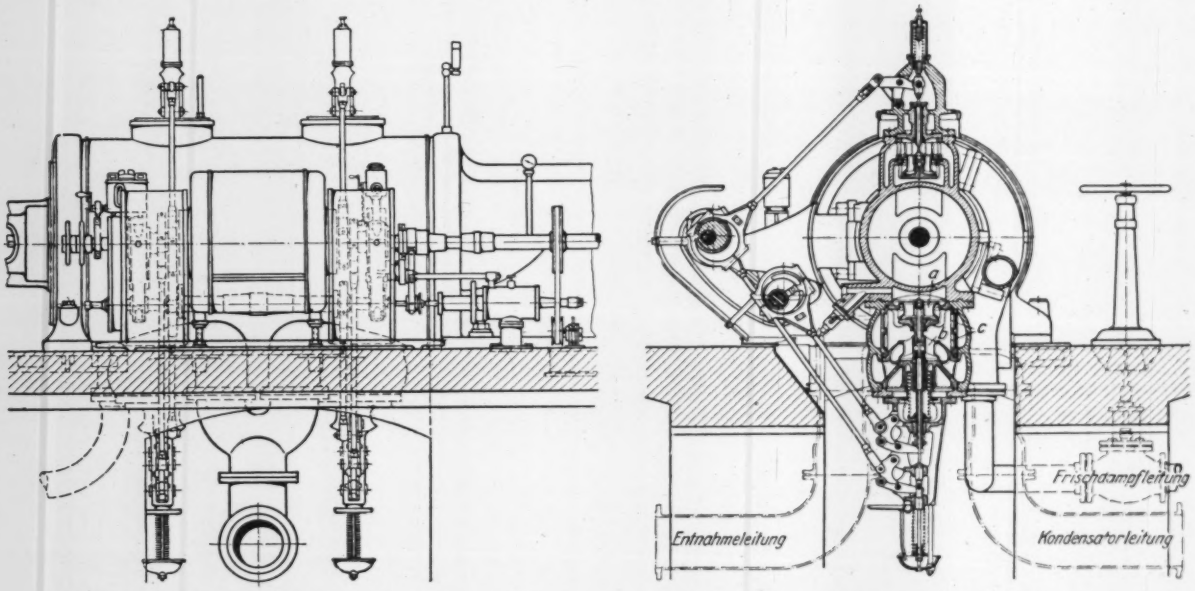
FIG. 6 SINGLE-CYLINDER ENGINE WITH COMBINED OUTPUT AND STEAM-EXTRACTION GOVERNING (BUILT BY HARTMANN)

also only one cylinder. The head end *B* works with extraction and is controlled by the extraction governor *a;* the crank end *A* works with condensation and the output there is controlled by means of the speed governor *b*. Here also both ends are set for the smallest cut-off in case of the engine overrunning its predetermined speed. But in this case the end *A* can run completely idle.

A further step in this direction is represented by the single-cylinder extraction engine of Starke and Hoffman, Figs. 7 and 8. Here at each end there are two exhaust valves, one above the other, the valve *a* being independent of the governor and set on a fixed exhaust lead of about 10 per cent and a 10 per cent compression, while valve *b*, which is controlled by the extraction governor is set also for 10 per cent exhaust lead but for a variable compression which may change from 30 to 110 per cent. In the latter case the valve does not open at all. The space back of this valve is connected with the condenser, while the space between *a* and *b* is connected with the extraction piping, and in this latter space there is a non-return valve *c*, which closes when the pressure falls below the extraction pressure.

If no exhaust steam is being taken, valve *b* opens wide and sets the compression for around 30 to 40 per cent just as in an ordinary single-cylinder condensing engine; this compression is maintained until the closing of valve *a*, which means up to about 10 per cent before the dead center.

If extraction steam is being taken the governor adjusts for a



FIGS. 7 AND 8 SINGLE-CYLINDER EXTRACTION ENGINE BUILT BY STARKE & HOFFMAN, HIRSCHBERG, SILESIA
(*a*, *b*, exhaust valves; *c*, non-return check valve; *entnahmeleitung* = extraction-steam piping; *frischdampfleitung* = live-steam piping; *kondensatorleitung* = condenser pipe.)

to the sum of their outputs. In such a case the thing to do is to supply the extra demand for exhaust steam either from the live-steam piping or from accumulators. Such an arrangement is to be adopted when it is desired to increase the power output of a plant by the installation of a second unit. A figure in the original article shows how both output and exhaust-steam governing may be combined in the same engine. One of the disadvantages of the arrangement here shown is that when the prescribed speed of rotation is exceeded there is a minimum cut-off in one of the cylinders. Furthermore, some of the steam is always lost by going to the condenser. Fig. 6 shows how these disadvantages can be taken care of. In this case there is higher compression and the cylinder remains connected with the condenser from the beginning of exhaust lead up to the end of the compression. From then on the pressure of the steam in the cylinder rises until it reaches the level of the extraction pressure; when this opens the non-return valve also opens and the exhaust steam passes into the extraction piping up to the time when valve *a* at 10 per cent ahead of dead center shuts off the cylinder.

The greater the compression as determined by the position of valve *b*, the more steam is take away. When 100 per cent steam is extracted, valve *b* is closed completely and hence no steam goes into the condenser. The diagrams in Figs. 9 and 10 show

the various stages of steam extraction. This construction has the advantage that it permits extracting up to 100 per cent of the steam delivered to the engine, and the output of the latter can be carried up to maximum even when no extraction steam is used. Furthermore, when 100 per cent extraction steam is taken the output of the engine can reach very nearly its maximum value, provided we neglect the part of the diagram area located under the back-pressure line. At full extraction no steam is lost in the condenser.

SWITCHING THE ENGINE INTO THE POWER AND HEATING SYSTEM OF THE PLANT

All extraction and bleeder arrangements are characterized by the fact that in the extreme case one can take from them only as much steam as is supplied to the engine in the form of live steam. If the plant operation needs more steam than that for heating purposes, it must be drawn either from the boiler or from the steam accumulator. This may be arranged to take place automatically at a time when the extraction valve is wide open and still, because of the great demand for steam for heating, the extraction pressure continues to drop. Live-steam additions however, unfavorably affect the economy of the plant because the pressure energy is lost or an expensive steam accumulator has to be installed. There is one way of solving this problem when possible, and that is to draw upon other concerns in the neighborhood which have heating steam to spare.

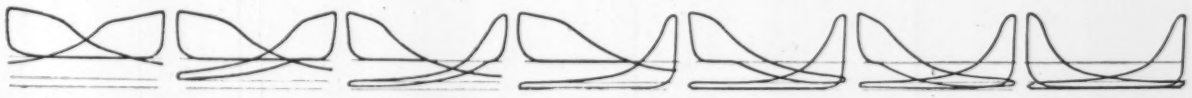


FIG. 9 DIAGRAMS TAKEN FROM AN EXTRACTION ENGINE WITH VARYING DEGREES OF EXTRACTION

[Cylinder diameter, 550 mm. (say, 22 in.); stroke, 650 mm. (say, 26 in.); 150 r.p.m.; 350–400 i.hp.; 9.4 atmos. (133.7 lb. per sq. in.) pressure; 275 deg. cent. (527 deg. fahr.) live-steam temperature; 2.4 atmos. (34.1 lb. per sq. in.) extraction-steam pressure.]

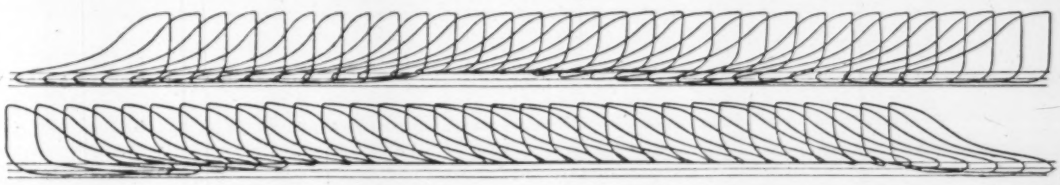


FIG. 10 CONTINUOUS DIAGRAM TAKEN FROM AN EXTRACTION ENGINE

[370 mm. (14.56 in.) cylinder diameter; 750 mm. (30 in.) stroke; 102 r.p.m.; 120 to 170 i.hp., 10.5 atmos. (149.3 lb. per sq. in.) pressure; 300-deg. cent. (572 deg. fahr.) live steam; 0.95 atmos. (13.51 lb. per sq. in.) extraction pressure.]

The introduction of a reciprocating engine as a part of the power and heat generating system has led to many interesting arrangements. One installation built by A. Borsig for a textile, plant in eastern Asia shows well the suitability of the reciprocating engine for this purpose. The two-crank engine has two equal cylinders, operates with back pressure, and when the power demand is great can be run either as a tandem or a compound engine (cylinder ratio 1 : 1) with interstage extraction. Under this arrangement the low-pressure side delivers very little power. In case of emergency, when one side fails, the unit can be run as a single-cylinder engine. The revolutions governor can work either on the right-hand or on the left-hand side, or on both sides, while the extraction governor and the valve gear drive may be uncoupled completely. If one side of the engine is cut out, it is of course necessary to uncouple the corresponding connecting rod. All the other adjustments are made by engaging or disengaging simple couplings or by changes of valves. (J. Kluitmann in *Zietschrift des Vereines deutscher Ingenieure*, vol. 71, no. 46, Nov. 12, 1927, pp. 1601–1608, 19 figs. *dcA*. Only the first instalment is here abstracted.)

Short Abstracts of the Month

AERONAUTICS

Air Power

A LECTURE before the Royal United Service Institution on this subject was given September 7, 1927, by Group Capt. W. F. MacNeece Foster, who among other things was the British Air Staff Representative at the Disarmament Conference of the League of Nations. According to the lecturer, an attempt to meet adequately the local needs of empire air defense would cripple the financial resources of the empire. The only possible way to deal with the situation was therefore to secure intense mobility of air power.

All stages of military progress were in a stage of acute transition. A spirit of investigation was abroad. Air power had exactly the same definition as military power in its essential objects. But in detail it consisted of (1) the number, morale, and skill of pilots, (2) the quantity and quality of the aircraft, and (3) the ground organization, which last included skilled mechanics without which the pilots and machines would be useless.

Air power also needed reserves of personnel and material. No country could afford to maintain in peace the forces required in war, and, with air power particularly, it was necessary to attain the highest possible power at the very beginning of the war. The short-service commission system was an endeavor to solve the problem of direct reserves of personnel. But the problem of direct reserves of material had not been solved, although no subject received more careful attention from the Air Ministry. Obviously large reserves of aircraft would soon become obsolete.

With regard to the indirect reserves, these were essentially governed by the potential wealth and industry of the country—a matter of primary importance but outside the scope of the present lecture. The other indirect reserve of air power was civil aviation.

There were, the speaker continued, two schools of Continental thought with regard to civil aviation and its adaptability for offensive purposes. There was what might be called the German-American school of thought, which ruled that civil aviation was a great normal industry, the success of which rested in its ability to pay its own way. Therefore every part

of an airplane must be designed for economy and efficiency. The pilots were purely peaceful, and as they got no drill or military training, would be useless in war.

The other view on the Continent was that civil aviation was maintained in practically every country with the help of government subsidies, and those who paid the piper would call the tune, with the inevitable result that aircraft built obtensibly for civil purposes, owing to these government subsidies, would be so designed that they could take part in war.

The British attitude was that both schools of thought were going too far and that vital details were ignored in both cases. Undoubtedly civil aviation was a most valuable form of reserve. A country which had an efficient form of civil aviation to draw from in time of emergency would undoubtedly be in a stronger position than a country which had none. The training of pilots and mechanics, with a certain amount of modification, could be made to serve both purposes. From an internal point of view civil aviation was an uphill business in Great Britain, and it would therefore be to that country's advantage to concentrate on empire aviation.

Nothing would reconcile Great Britain to spending enough money on air power to make it effective unless it could be proved that air power was absolutely vital. That it was desirable was not enough. The acid test of its relative value was to compare it with sea power.

A fact that was becoming increasingly clear was that the next European war would be a war against the civil population. Sir Henry Wilson had said that no convention or treaty would prevent an unscrupulous enemy from using poison gas. A German general officer had written:

"The war (of the future) will frequently have the appearance of destruction *en masse* of the entire civil population rather than a combat of armed men."

It was therefore obvious that one must consider the means, even though one disapproved of them, which adversaries might employ. The danger of restrictions of methods of warfare was so wide as to make restriction Utopian.

The conclusions to be drawn seemed to be that: (1) The navy alone could not secure safety, and that the navy and the air force were each vital to the security of the country. (2) The passive defence of Great Britain by air was at best only a palliative. The position of the offensive *vis-à-vis* the defensive was becoming stronger with the trend of air scientific management. (3) The scope of modern warfare would increase enormously and would include the civil population. (4) The large passenger-carrying aircraft might, particularly at night, be of the greatest value in bombing attacks. (5) Ethically and strategically it was desirable to limit the more barbarous phases of air warfare—and on the other hand it was essential to be prepared. (*The Aeroplane*, vol. 33, no. 24, Dec. 14, 1927, pp. 781–782 and 784, *gA*)

AIRCRAFT ENGINEERING

The Russell Parachute

THIS parachute, called the "lobe" type, was designed primarily for military use. A pull on the rip cord instantly removes the entire covering. In the open position the canopy is extremely flat across the top with the sides curving downward and slightly under. The main supporting cords are attached to the skirt or bottom edge of the canopy fabric. From this point the cords remain free of the fabric until entering the seams on the periphery of a smaller circle forming the center top of the canopy. This allows the loose annular rings of fabric so formed to fill out regardless of the load or tension on the shroud lines. In filling with air the position and movement of this annular ring are governed directly by the internal and external pressures acting upon the canopy.

At the start of opening this annular ring forms a relatively slight angle with relation to the line of flight. As the opening progresses this angle of the annular ring increases until in the full-open position the ring is at right angles to the path of descent. The annular ring in the open position then takes the shape of a semi-circular lobe projecting from the center portion of the canopy. By reason of the fact that over half of the fabric area of the canopy comprising the lobe is not held to a given position by the confining tension of the shroud lines, extremely positive opening is said to be assured. In the conventional parachute the accelerating load in one direction with the resultant drag upon the canopy in the opposite direction, causes a tension upon the shroud lines resisting the opening of the parachute. In the lobe-type canopy well over half of this resistance is eliminated.

The details of the parachute, including the characteristics of materials, are given in the original article. (J. M. Russell in *Aviation*, vol. 23, no. 26, Dec. 26, 1927, pp. 1508–1510, illustrated, *d*)

ENGINEERING MATERIALS

Cindal—A New Aluminum Alloy

A NEW TYPE of aluminum alloy has been recently put on the market. This alloy is primarily intended for corrosion resistance, but is said to have certain other interesting characteristics. It has been found during the course of the research which led to the development of this alloy that aluminum alloys containing copper in quantities of over 2 per cent are poor from the point of view of ability to resist corrosion, while alloys containing higher amounts of copper have inferior mechanical properties (brittleness).

Cindal alloys are produced by a process somewhat similar to the bessemer with the exception that chlorine gas or a gaseous compound of chlorine is used for blowing instead of air. Also a special furnace is used instead of the standard bessemer converter. During the process a rise of temperature occurs which must be carefully controlled as otherwise failure will result. As gassing proceeds a dry gray-black powdery dross forms on the surface of the metal. This dross reacts with the air present and sets up a brisk reaction of the thermit type. When the process is completed the surface reaction subsides and a white powder takes the place of the gray dross. This white powder consists essentially of alumina and indicates that purification is complete. The metal is then ready for use and may be employed in making castings or for the production of ingots. Alloys treated by this process are said to possess greater fluidity on account of the removal of oxides, carbides, and dissolved gases.

A series of ten alloys were tested for corrosion-resisting properties in two different conditions: Firstly, as melted, mixed, and cast in the ordinary way, and secondly, after treatment by the above process using chlorine gas. The gas was passed through the molten alloy for a period of about four minutes. In this test the specimens were cleaned at regular intervals of one month by means of a hard bristle brush. Standard bend-test specimens were also prepared in order to ascertain the effect on ductility of the refining process. A small bend-testing machine was designed for this purpose. The standard test piece is placed across two rollers and bent over a $1^1/_4$-in. radius by means of a screw-operated push rod until the specimen is just seen to crack. This is done by observing the polished underside of the specimen in a suitable mirror. The average bend angle of six test pieces is taken. This simple form of test

has avoided the preparation of a large number of tensile test bars. This corrosion test proved that the treated alloys were much more resistant to corrosion than the same alloys which had not been treated. This test has also confirmed all previous tests that have been made with regard to the chemical composition of the alloys.

The effect on microstructure and general appearance of alloys which have been treated by the chlorine compound is of interest. In normal alloys an increase in specific gravity of up to 8 per cent has been obtained by this method. The resultant castings besides being quite free from unsoundness, are greatly improved in appearance, tensile strength, and ductility. At the same time, the apparent freezing range is diminished and the casting properties are much improved. When normal metals and alloys are cast in chill molds a deep pipe is produced. Underneath this pipe unsoundness due to shrinkage or lack of feeding always occurs. This is not so with alloys which have been treated by the chlorine-compound refining process.

Data of tests (sea-water and spray, as well-accelerated corrosion) have been made and are described in the original article. From these it would appear that Cindal alloys have quite a superior ability to resist corrosion. (D. R. Tullis in *The Metal Industry*, vol. 31, no. 21, Nov. 25, 1927, pp. 487–490, 7 figs., *d*)

FOUNDRY

Centrifugal Castings for Diesel Engines

THIS paper deals chiefly with the manufacture of liners and piston-ring drums, from which piston rings are turned. It is quite difficult by ordinary molding to make a plain cylindrical casting, particularly when the casting is required to be machined all over and to show no traces of unsoundness or surface blemishes. This is particularly so with the type of special iron usually desired in Diesel-engine cylinder liners and piston rings. Many of these difficulties can be eliminated by the use of a feeder head, but even this does not remove all traces of unsoundness. The author describes the centrifugal-casting process developed by his company to meet this condition.

In the centrifugal casting of piston-ring drums the total carbon appears to be a controlling factor of elasticity, high values of the latter being generally associated with low total-carbon content. The requirements of the larger internal-combustion-engine and Diesel-engine piston rings have not been standardized in the same manner. It is customary for centrifugal-casting manufacturers to endeavor to work to the lower limit of silicon content given by the British engineering standards specification (No. 5004—compare Air Board specification 3K. 6). The same typical results obtained on large Diesel-engine rings are given in a table in the original article. As regards resistance to wear and heat conditions, the following factors are considered generally valuable: low silicon content, low total-carbon content, high combined-carbon content, as well as grain size and condition of the combined carbon. The author next discusses the so-called spun sorbitic castings. This development is designed to enable cylindrical castings to be produced in low-silicon and low-total-carbon irons with the maximum of combined carbon compatible with commercial machinability. In this case instead of a metal mold is used a sand-lined mold. The refractory mold enables the low-silicon-content iron's commercial machinability to be obtained easily, and in addition enables producing engine liners with ports, waterway passages, and flanges. (J. E. Hurst in a paper read before a meeting of the Diesel Engine Users' Association; abstracted through *Foundry Trade Journal*, vol. 37, no. 591, Sept. 15, 1927, pp. 199–201, 5 figs., *d*)

MECHANICS

The Strength of Riveted Joints Under Load

ONE OF THE subjects which is being reconsidered by engineers is the question of the action and strength of riveted connections when made up of high-strength plates fastened with high-strength rivets. The present paper deals with tests of riveted joints carried out by the U. S. Bureau of Construction and Repairs of the Navy Department. The work was directed primarily to the study under tensile forces of slip phenomena and stress distribution in riveted joints. In addition study was made of the effect upon the ultimate strength of the joint of variations in rivet spacing, and attention was also directed to the effect of using rivets of a grade softer than the material of the plate.

Three grades of material were used for the main plates: medium steel and high-tensile steel which are standard Navy materials for sheet construction, and special-treatment steel such as used for armor plate. Two of these grades, the medium and high-tensile steels, were used for the straps. Two grades of rivets were used—medium steel and high-tensile steel. Among others the following conclusions were arrived at:

Slip Resistance

When the joints are fabricated throughout of medium steel, the stress in the main plate at which slip first occurs increases with the number of rivets.

On account of a probable "quilting" action in the cover plates during the riveting of a multiple-row joint, joints containing four or more rows of rivets show inferior slip resistance.

Symmetrical joints in which alternate rivets are omitted in the outer row show relatively the same rivet performance as shown by solid-row joints. It is probable that the same conclusion applies to staggered riveting.

Joints in which one butt strap is wider than the other give erratic performance and show inferior slip resistance as compared with symmetrical joints.

Joints fabricated of high-tensile steel show resistance to slip greatly inferior to that shown by medium steel, and so low that it appears doubtful whether any great portion of the load could be considered as carried by frictional forces. This suggests that joints made of high-tensile steel would "pull loose" at low plate stresses.

The low slip resistance of high-tensile-steel joints seem to be primarily due to the initially warped condition of this material as compared with medium steel, also perhaps to a difference in the shrinkage of the rivets on cooling.

In terms of single-shear stress, the stress in the rivet at which the first slip occurs is so much lower than customary design shear stresses, and is so greatly affected by the number of rivets in the joint and the effects of eccentric loading and bending, that it does not appear desirable to design riveted-joint construction on the basis of frictional resistance, but rather on the commonly used method of proportioning on shearing and bearing.

Joint Efficiencies

Double-strap butt joints failing in shear will develop the full theoretical shearing strength.

Where the plate material has not been left in the injured condition caused by punching, a plate failure through the next section of full-row chain riveting may be expected to show a strength in excess (possibly 10 per cent) of the theoretical value.

The omission of alternate rivets in the outer row causes a loss in strength in the net-section failure as compared with full-row riveting, and may even show less than theoretical strength.

The unsymmetrical joint shows no advantage in efficiency over similar symmetrical types.

LOAD PARTITION AMONG RIVET ROWS

The frictional resistance of a joint fails at such low plate stress that for practical purposes the load partition among rows may be considered as dependent upon the bearing and shear resistance of the rivets.

At low loads the outer row of rivets carries the greater proportion of the total load, the amount carried by the inner rows decreasing with the number of joints. The test results at low loads (except for double-row joints) show fair agreement with theory.

Double-row joints in test show the outer row carrying initially 80 per cent of the load, and throughout the test never less than 66 per cent of the load. This suggests that for important work the use of double-row joints is questionable.

As plate-stress intensity increases the proportion of the load carried by the first rivet decreases. This action tends to cause equalization of load between rivet rows, and suggests the desirability of having only ductile material around rivet holes if good distribution is to be obtained.

The stress at which load equalization takes place increases with the number of rivets in the joint, and may occur within commonly accepted design plate stresses, provided the joint does not have too great a number of rows. Practically, this means that for the more common-type joints the usual assumption of uniform stress distribution is nearly true for the customary design plate stresses.

Certain conclusions were arrrived at affecting design, in particular that of the double-strapped joint. In this case it was found that the joints should be designed to have a shearing strength in excess of the calculated plate strength. For a given number of rows those joints having all rows complete show the highest slip resistance. Furthermore, while the slip resistance of the medium-steel joints is generally consistent with the number of rivets, the high-tensile-steel joint shows very erratic performance, having in general about half or less of the resistance shown by the same type of joint in medium steel. The features of construction that give the best slip resistance are among other things as follows:

The use of joints in which all rows of rivets are complete.

The use of two-ply material where the highest stresses occur.

This latter feature is obtained in using two courses of plating for shear strakes and main deck stringers, where one of the courses serves as one of the butt straps for joints in the other course. The presence of quilting rivets restrains relative motion between the two courses, and thereby reduces slip—i.e., relative motion—at the joint.

The use of ample rivet area in the plate seams. The occurrence of slip in a joint throws a high concentration of stress into the adjacent strakes opposite the joint. If the plates of the strake containing the joint are connected to the adjacent strakes by ample rivet area, the slip that would otherwise occur will be restrained, and, further, instead of a concentration of stress in the passing strakes opposite the joint, there will be a gradual distribution into the adjacent plates of so much of the load as could not otherwise be carried across the joint without slip.

The substitution of medium-steel rivets for high-tensile-steel rivets in joining high-tensile-steel plates.

Medium-steel rivets may be used without disadvantage with harder plates, as it appears that the nature of the plate material has but little, if any, effect upon the rivet strength in shear.

From the standpoint of partition of load between the rows of rivets there is one observation of immediate practical application, namely, the fact that the disparity in load between the outer and inner rows of rivets does not disappear in the double-riveted joint within the yield point of the material. This leads to the principle that important joints should always have at least three rows of rivets.

The data obtained from the test joints, which were made from 30-lb. plates with 20-in. cover plates, and 1-in. rivets spaced $4^1/_2$ diameters apart, are satisfactory for drawing general conclusions as to the behavior of joints with other plate thicknesses and rivet diameters, since the conclusions rest upon fundamentals which are exemplified in the test joints. With regard to the factors derived for ultimate strength of joint, it is possible that the increase in plate strength for joints with all rows complete might be less with a wider rivet spacing, although the factor given (1.05) anticipates such reduction, this being the least gain observed (the maximum gain was 10 per cent). The straps were relatively heavier in the test joints than required by the riveting specifications The effect of using a lighter strap would be to reduce the proportion of load taken by the outer rivets and perhaps reduce the loss in strength observed in the joints having alternate rivets omitted in the outer rows The factor given (0.93) is therefore on the safe side. The remaining conclusions and suggestions obviously may be made general in application. (E. L. Gayhart in a paper read before The Society of Naval Architects and Marine Engineers. For abstract compare also *Mechanical World*, vol. 82, no. 2135, Dec. 2, 1927, pp. 418–420, 1 fig. and tables, *p*)

A Simple Method of Determining Stress in Curved Flexural Members

CURVED members subjected to bending, such as crane hooks, frames for punches and drill presses, members in railway trucks, chain links, etc., are important elements in many engineering machines and structures. It is generally understood that the ordinary flexure formula, which gives reliable values for the primary stresses in straight beams or flexural members, gives values for stress that may be much too small when applied to curved flexural members. Nevertheless this straight-beam formula is still widely used in the design of curved flexural members.

The main reasons for applying the straight-beam formula to curved beams are probably that the curved-beam formula is much more complicated and difficult to apply than is the straight-beam formula, and that, in the case of cast frames, the deviation from the assumed condition of homogeneity of material, as well as the presence of initial stresses, causes uncertainty as to the significance of the calculated stresses.

Due to the shorter length of the fibers on the concave (or inner) side of a curved beam the unit strain (and hence also the unit stress within the proportional limit) is greater than that given by the straight-beam formula and the stress on the convex (or outer) side is less. Likewise the neutral axis does not pass through the centroid of the cross-section of the beam but lies nearer to the concave or inner side.

This increase in stress due to the curvature of the beam may be of great importance, especially in members in which the stress is repeated many times, as is frequently the case.

There are several formulas available for the calculation of these stresses. First comes the straight-beam flexure formula Next is the Winkler-Bach formula, the full derivation of which is given in an appendix to the bulletin here abstracted.

The following are the conclusions at which the authors arrive:

The straight-beam flexure formula is radically in error when applied to curved flexural members of relatively sharp curvature, and this error is probably responsible for many failures of curved flexural members, particularly when the members are subjected to impact and to repeated stress.

The Winkler-Bach formula for curved beams, although reliable, is difficult of application.

The stress in curved beams can be satisfactorily calculated by the ordinary straight-beam flexure formula used with a correction factor. Values of the correction factor for any sections likely to be used in structural and machine members may easily be obtained by use of the table or equation given in the original bulletin.

The stress computed by means of this corrected straight-beam formula applies only to the extreme fibers of the member. But, since the significant stress usually occurs at an extreme fiber, the method offers a simple, satisfactory, and practical means of designing curved flexural members.

In the appendixes are given expressions for section property Z, which is a property of the cross-section defined by a certain integral expression, as well as a graphic derivation of the same Z by the line-polygon method. This method, devised by A. E. Hershey, is slightly more accurate than the "link rigidity" method and does not necessitate the use of a planimeter or other area-measuring device. [Benj. J. Wilson (Mem. A.S.M.E.) and John F. Quereau, *University of Illinois Bulletin*, vol. 25, no. 20, Jan. 17, 1928, Circular no. 16 of the Engineering Experiment Station, 20 pp., 5 figs., *t*]

MEASUREMENTS

Metering Air, Gas, Steam, and Other Industrial Fluids

A PAPER on some recent developments in this field was presented at a meeting of the Midland Institute of Mining Engineers on November 18 at Sheffield, England, by John L. Hodgson. Among other things, the author described a rotary steam meter of his own design which enables one to measure accurately steam in small mains. This meter consists of a turbine driven by steam which impinges on it from two symmetrically placed nozzles. The speed of the turbine is kept low by a liquid damping device, and the retarding torque is made sufficiently large to mask the effect of the torque due to the rotation of the slow-moving turbine in the steam so that a one per cent change in the density of the steam involves exactly a $\frac{1}{2}$ per cent change in the value of the corrective factor governing changes in the density of the steam. Hence, unless the pressure varies over a wide range, it is not necessary to equip the meter with an automatic pressure-correcting device. The motion of the turbine is transmitted to the counter dial by means of a magnetic drive. The meter may be also used on a bypass across an orifice placed in a large main. Another development of the rotary meter principle is the shunt air meter, Fig. 1.

Here a turbine, the speed of which is damped by a fan F, is inserted in a shunt circuit across an orifice O, and driven by the discharge through the two nozzles N. The counter mechanism rotates in an oil bath, which is filled through the plug P, and the bottom pivot is lubricated by oil which escapes from this chamber down the hollow turbine spindle. The turbine is entirely protected from damage due to overload by the valve V, which closes down and shuts off the shunt circuit when the flow exceeds about 40 per cent of the nominal full flow.

This meter has been designed to enable a counter record to be obtained in order to apportion departmental costs, or to ascertain the amount of air used by a given pit or pit level, so that the cost of compressed air per ton of ore or coal raised can be worked out.

The shunt-type rotary meters above described are accurate to within plus or minus 2 per cent down to one-tenth of the maximum flow, the relative shapes and the proportions of the nozzles and the main orifice having been carefully worked out experimentally to render this result possible. A feature of these meters is that they form one of the simplest and most accurate methods of obtaining a counter record of the flow of "clean" fluids (among which steam, air, and most gases can be classed), as there is only one rotating spindle, apart from the counter, to be kept in proper order. Even when the fluid to be measured contains dirt or other extraneous matter, it is carried along the main body of the stream and does not get into the shunt circuit. The meters should be installed horizontally, with about ten diameters of parallel pipe of the same bore as the meter in front of them, and with about five diameters of similar pipe on the downstream side. The meters can then be checked for accuracy *in situ* by fitting a manometer or a recorder across pressure holes drilled on the upstream and downstream sides of the main orifice.

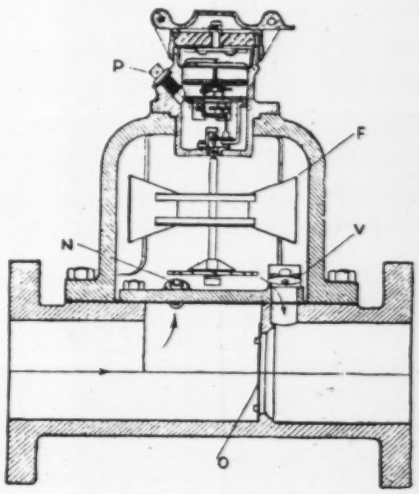


FIG. 1 SECTIONAL ELEVATION OF HODGSON SHUNT-TYPE ROTARY AIR METER

The original article shows also a spring-controlled gate-type air-flow indicator. In this case when the motor is overloaded the edge of the gate can pass beyond the opening of the ports and so gives a free passage to the air or gas. These meters have been specially designed for ascertaining the air consumption of individual drills, coal cutters, and haulage engines. There is also a recording and integrating meter of the gate type, which is said to be extremely sensitive and very rapid in response to changes in the flow.

In the discussion which followed one of the speakers mentioned the difficulty which he had experienced in the installation of such meters. For example, in the spring-controlled gate-type air recorder, the two vertical pipes were welded on to the mains, which was a difficult thing to do underground. (*Iron and Coal Trades Review*, vol. 115, no. 3117, Nov. 25, 1927, pp. 795–796, 7 figs., *d*)

POWER-PLANT ENGINEERING

The First Industrial High-Pressure Steam Plant in Switzerland

IN A SUB-TITLE the plant described here is called an example of a small modern power station. There are two fundamentally different types of steam-turbine plants, namely, those in which the only purpose is current generation, and those in which the exhaust steam of the generating turbine set is used for manufacturing purposes. With the first type efficiency is the controlling element. Yet in spite of all improvements the heat requirements of the best plants of this type are said by the author to be rarely less than 3000 metric heat units (12,000 B.t.u.) per kilowatt-hour. Consequently, the consumption and

price of coal influence most decisively the cost of a kilowatt-hour.

The actual heat required to produce a kilowatt-hour in a plant of the second type, even though it is one of the smallest, is only about one-third of that which would be required by the most efficient large power station. Under these circumstances the deciding factor in the cost of generating of a kilowatt-hour is not the price of fuel but the initial cost. For plants which form the subject of this article, i.e., those in which the exhaust can be used completely in the form of steam, back-pressure turbines are given foremost consideration. There are, however, also industrial concerns in which large quantities of warm water are required, and for these back-pressure turbines would be unsuitable. The electrical system may involve parallel operation or some such system as the following. Two bus bars are provided, one being supplied from the small power station and the other from an outside network. The outgoing lines to the works can be connected as a whole to either of these bus-bar systems. If it is desired to change over the connection of an outgoing line from one bus-bar system to the other without causing a disturbance in the works, the small power station is temporarily connected in parallel with the network. The change over is made and then the two systems are again separated. The way the bus-bar systems are arranged is shown in a diagram in the original article, this example being taken from the plant of Jenny & Co., Aarau, Switzerland.

The plant in Aarau is a typical example of the small plant under discussion. In designing the plant it was known that during working hours about 6000 kg. of steam per hr. would be required for heating purposes and about 250 to 300 kw. of electrical energy, chiefly for supplying motors. Although two old boilers with large water space were on hand, it was nevertheless considered to be economically desirable to purchase a high-efficiency boiler.

In view of developments to be made in the future it was decided to install an inclined water-tube boiler with a capacity of 10,000 kg. of steam per hr. and having a heating surface of 350 sq. m. As it was known that by using live steam at a sufficiently high pressure and temperature it would be possible to generate the necessary electricity more cheaply than it could be obtained from a power-supply company, it was decided to use the superheated steam first for generating purposes in a back-pressure turbo set. This installation constituted the first high-pressure plant in Switzerland; the steam was used at a pressure of 35 kg. per sq. cm. (497 lb. per sq. in.) gage and 400 deg. cent. (752 deg. fahr.) at the boiler.

The boiler has two drums at the bottom and three above, together with a steam collector. Each of these drums is made in one piece, the material being 42 mm. (1.62 in.) thick. The boiler has a large water volume—35 cu. m. (1236 cu. ft.)—in order to be able to deal with peak loads. The feedwater is admitted to the rear drum, from which it flows and deposits any sediment in the bottom rear drum. It now passes up to the middle drum, from which it descends to the front lower drum and from this one up to the top front drum, from whence the steam produced passes into the steam collector. Throughout the whole of its course through the boiler the water flows in a direction opposite to that taken by the flue gases. From the collector the steam passes through the superheater to the turbine. The cross-sections of the parts of the boiler are so amply dimensioned that even under sudden loading no water is carried over with the steam. The boiler is provided with a mechanical stoker.

The steam passes from the boiler through the turbine and sometimes directly through a throttle valve into two old firetube boilers and thence to the dye works. The firetube boilers which are never fired serve the purpose of steam accumulators and equalize temporary large demands of power and heat. The turbine is a Brown-Boveri reaction back-pressure machine with a cast-steel casing and one impulse wheel which permits ample quantity regulation. The speed of the turbine is 5000 r.p.m., which is reduced to the alternator speed of 1500 r.p.m. by means of practically silent gearing. There is no back-pressure regulator as the back pressure is adjusted by hand by means of a live-steam throttle valve which maintains the pressure in the low-pressure boiler above a fixed amount. In service the back pressure is kept lower than originally intended and checked by an attendant at about every half-hour. The man checking the pressure knows that should a certain minimum value be recorded he must increase the opening of the regulating valve of the bypass line. At the moment of the large superheated-steam injections which occur once or twice daily the low-pressure boiler does not deliver sufficient exhaust steam, as its evaporative surface is too small. The pressure in the heating lines of the factory then sinks to such an extent that a larger part of the live steam already throttled by the manually operated reduction valve must be supplied to the heating lines of the factory by way of an automatic auxiliary valve. The steam thus becomes somewhat superheated by the additional steam, and this system is claimed to have worked out very well in practice.

During the night some steam is also necessary and service is maintained in the following manner: In the evenings the turbine and high-pressure boiler are shut down. The steam is supplied from the latter to the low-pressure boiler by way of the throttle valve, and at about midnight a pressure of some 10 kg. per sq. cm. (142.2 lb. per sq. in.) is found in the low-pressure boiler, which is then full. The high-pressure boiler is now shut down and the steam for the factory is supplied from the low-pressure boiler alone. The pressure in the high-pressure boiler does not decrease, but as a result of the heat contained in the brickwork it increases at first; afterward it falls, until, in the morning, there is a pressure of about 10 kg. per sq. cm. (142.2 lb. per sq. in.) in the high-pressure boiler. In the low-pressure boiler, on the contrary, the pressure has fallen to a few atmospheres. In about an hour the freshly banked boiler is at full pressure and at the same time the low-pressure boiler is charged to about 10 kg. per sq. cm. (142.2 lb. per sq. in.); hence at the beginning of the working day a large quantity of heat is available for the baths of the dye works. During the first hour up to 14,000 kg. (30,800 lb.) of steam are required.

Figures of an estimate of the approximate outlay and generating cost per kilowatt-hour are given in the original article in Swiss francs. (J. Broggi in the *Brown-Boveri Review*, vol. 14, no. 12, Dec., 1927, pp. 327-333, 11 figs., *dp*)

RAILROAD ENGINEERING

The Sulzer Diesel Locomotive

A LOCOMOTIVE was recently supplied to the Tunisian Railroad Co. in which the normal output of the Diesel engine was rated at 250 b.hp. The Diesel engine is direct coupled to a dynamo supplying current to the four motors driving the four axles of the locomotive by means of spur gearing. The specifications are that the locomotive shall be able when drawing a load of 80 tons to develop a speed of 37½ m.p.h. on the level, 23 m.p.h. when ascending a gradient of 1 in 100, and 12 m.p.h. up a gradient 1 in 70.

In trials the locomotive drawing a full load of 80 tons on the level showed an average fuel consumption of 0.028 lb. per ton-mile. The locomotive is equipped with a Sulzer airless-injection four-cycle Diesel engine with the eight cylinders arranged obliquely. Running at 550 r.p.m. the engine develops 250 b.hp., but the output may be raised temporarily to 300. The engine is started by the generator as a motor with current from the

storage battery. When the engine has reached normal speed the generator is automatically switched over to act again as a generator. The storage battery is then again automatically charged up from the charging generator.

All working parts are provided with forced lubrication. The cylinders are water cooled, the cooling water flowing in a closed circuit and being circulated by means of two centrifugal pumps driven by the engine itself. The warm water from the cooling jackets is led to a cooler set on the roof of the locomotive and provided with a powerful fan. Because of the hot water usually prevailing in Tunis, the temperature of the cooling water can be observed in the driver's cab by means of an electric thermometer. The electric part of the locomotive includes a special generator for charging the storage battery. It is designed for an output of 25 kw. and also supplies current for the fan motor. Data of tests are reported. (*Sulzer Technical Review*, no. 4, 1927, pp. 1–6, 7 figs., *d*)

REFRIGERATING ENGINEERING

A Mercury-Compressor Refrigerating Machine

THIS machine is based on the employment of a mercury compressor evolved from the Archimedes screw pump, originally described in a paper presented at the Annual Meeting of The American Society of Mechanical Engineers, December, 1926 (and published in MECHANICAL ENGINEERING, vol. 48, no. 11a, Mid-November, 1926, pp. 1228), by J. G. DeRemer, one of the authors of the present paper. In that case the principal axis of rotation was horizontal. Recently another design has been developed using a vertical type of machine, which, for reasons described in the present paper, was found preferable. The elements as now manufactured contain from 8 to 12 oz. of isobutane and from 8 to 9 lb. of mercury. On the neck of the element, which is hermetically sealed, there is a ball carried in a bearing cup backed with a suitable lubrication reservoir. This ball joint serves to support the weight of the element and the rotating frame. Since the motion of the element is that of a conical pendulum and the element itself does not rotate, the ball joint has only a slight rocking motion.

The novel feature of this refrigerating machine is the unitary structure hermetically sealed containing a minimum of refrigerant, no internal lubricant, and no internal moving parts. [J. G. DeRemer and R. W. Ayres (Members A.S.M.E.) in *Refrigerating Engineering*, vol. 14, no. 6, Dec., 1927, pp. 169–172, 7 figs., *d*]

Heat Transfer in Ammonia Condensers

IN THE refrigerating industry, where anhydrous ammonia has been the principal working medium, the desire for safety has been the factor which has had the most influence on the design of condensers. As a natural outgrowth of this desire, constructions involving pipes and pipe fittings have been accepted as a logical basis for design. Such constructions have been found to be safe, easily erected, reasonably efficient in the use of water, and moderate in first cost. With the various arrangements of pipe surface the common atmospheric and the bleeder types of condensers were developed. Further development resulted in the submerged, the shell-and-coil, the double-pipe, the flooded condenser of various designs, and finally in the horizontal and vertical shell-and-tube condensers. During this period the design also developed concurrently with a consideration of counterflow versus parallel flow of the water and the ammonia, and with an endeavor for proper and efficient disposal of the superheat contained in the ammonia gas at the inlet to the condenser. In all of the designs, however, safety was the primary thought, and efficiency and economy of operation were secondary.

Although tests of condensers have been reported at various times, the results have been isolated and more or less fragmentary. Accordingly, it seemed desirable to undertake a systematic and rather extensive program of research in order to correlate and give proper weight to the various factors entering into the design and operation of a number of outstanding types of ammonia condensers.

In order to compare the performance of the three condensers tested, both the unit condenser tonnage and the total condenser tonnage have been plotted against the unit water rate for an initial water temperature of 68 deg. fahr. These results are shown in Fig. 2. Apparently one square foot of surface is more effective in the double-pipe condenser than it is in the atmospheric bleeder condenser. Approximately the same increase in effectiveness with increasing water rates was obtained

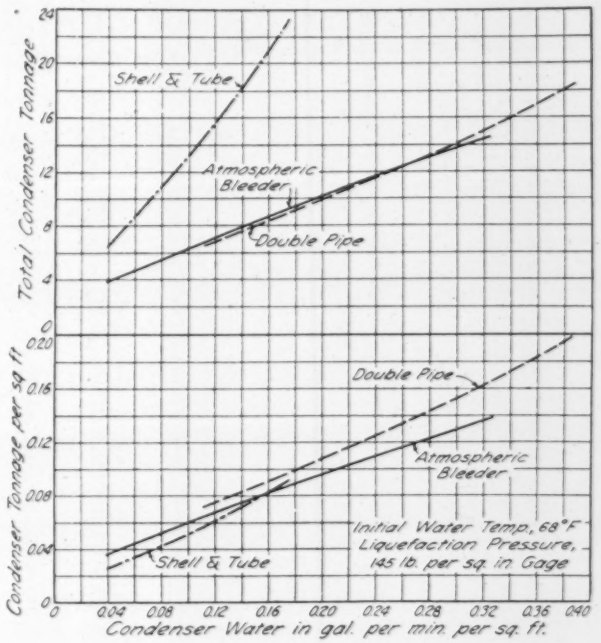


FIG. 2 COMPARISON OF THE PERFORMANCE OF THREE TYPES OF AMMONIA CONDENSERS

for both of these condensers. The rate of increase was much greater, however, in the case of the shell-and-tube condenser, and while the surface is less effective at low water rates than the surface in the other two condensers, it becomes more effective than either of the other two at water rates above approximately 0.20 gal. per sq. ft. per min. This effectiveness is undoubtedly influenced by the thickness of the layer of condensed liquid adhering to the surface, and the ability of the surfaces to clear themselves of the layer at higher rates of condensation.

When the total tonnage developed is taken into consideration it is apparent that the shell-and-tube condenser had the greatest capacity. The total area of the bleeder condenser exposed to saturated ammonia was 105.3 sq. ft., while that for the double-pipe condenser was 92 sq. ft. This difference slightly more than offsets the difference in effectiveness per square foot, and the capacity of these two condensers was practically the same. If the same external dimensions are retained, it is possible to obtain more area with the bleeder condenser than with the double-pipe, since the condensing surface is that of the inside pipes in the latter. The total surface exposed to saturated ammonia in the shell-and-tube condenser was 251 sq. ft. It is possible to obtain a greater amount of surface for the same

floor space with this condenser than with the others, and apparently the surface could have been much reduced and a rating comparable with that for the bleeder and double-pipe condensers retained.

A study of the coefficient of heat transfer for the three types of condensers may be made by comparing the curves in Figs. 15, 22, and 28 of the original article (not reproduced here). A water rate of 1.41 lb. per min. per sq. ft. of surface corresponds to a total water rate of 148 lb. per min. for the atmospheric bleeder, 130 lb. per min. for the double-pipe, and 352 lb. per min. for the shell-and-tube condenser.

The greater values of K indicate that at high water rates one square foot of the surface in the shell-and-tube condenser is more effective than one square foot in the other two condensers.

The greater spread of the curves for the shell-and-tube condenser indicates that the effectiveness of one square foot in this condenser decreases more rapidly with increasing values of θ_m than it does in the others. This is true for the constant water rate. If, however, a constant initial temperature for the water is maintained, and the water rate is increased, increasing values of θ_m are obtained. Under these conditions the effectiveness of the surface in the shell-and-tube condenser increases more rapidly than that in the others. See Fig. 2.

The amount of superheat in the gas entering the atmospheric bleeder and the double-pipe condensers does not materially affect the amount of surface exposed to the action of saturated ammonia vapor.

For still-air conditions, the loss in water due to splash from the atmospheric bleeder condenser ranges from 0.5 per cent to 8.5 per cent of the total water fed to the condenser. This amount would be increased if splash strips between the pipes were omitted.

The water adheres to the tubes in the shell-and-tube condenser in a fairly uniform layer and no appreciable amount of spray is formed.

The condenser tonnage is a function of the water rate and the initial temperature of the cooling water. High initial temperatures require high water rates to develop the same condenser tonnages.

The thickness of the layer of liquid ammonia adhering to the condensing surfaces materially affects the rate of heat transfer per unit of surface.

The effectiveness of the surface increases more rapidly with increasing water rates in the shell-and-tube condenser than it does in the bleeder and double-pipe condensers, and at water rates above 0.19 gal. per min. per sq. ft., with an initial water temperature of 68 deg. fahr., it becomes greater than that for the other condensers.

In the atmospheric bleeder and the double-pipe condensers from 37.0 per cent to 67.5 per cent of the total liquefaction may occur in the pair of pipes exposed to the coldest water.

No appreciable amount of subcooling of the liquid occurs under conditions comparable with those in these tests.

An advantageous design for a condenser is one in which the condensate is removed completely and immediately from the condensing surface. [Alonzo P. Kratz, Horace J. Macintire (Members A.S.M.E.), and Richard E. Gould in the *University of Illinois Bulletin*, vol. 25, no, 15, Dec. 13, 1927, Bulletin no. 171 of the Engineering Experiment Station, 58 pp., 30 figs., *eA*]

SPECIAL PROCESSES

Manufacturing Seamless Copper Tubes Electrolytically

A PROCESS has recently been developed in Germany for manufacturing seamless copper tubes and cylinders electrolytically. The characteristic feature of the process is that the metallic particles while being precipitated are subjected to constant mechanical working, which causes a unification of the deposit and produces physical properties in the resulting material such as are not obtained by any other electrolytic process.

The manufacture of a seamless copper cylinder according to this process is as follows: Copper ore is smelted and refined in a furnace, where the copper content is brought up to 97 to 98 per cent. The molten metal is then poured into cast-iron molds in the requisite shape for the anodes. These have the form of curved plates, the curvature approaching, as nearly as possible, the circumference of the cylinder to be produced. The anodes are inserted in lead-lined wooden vats measuring about $16^1/_2$ ft. in length and having a width of about 4 ft. They are placed as nearly as possible concentrically around the cathode, which consists of a perfectly straight and truly cylindrical length of copper tubing fitted with bottoms and journals at both ends. The journals are placed in bearings so that the cylinder can turn around freely. Sometimes a fusible-metal core is used instead of the copper cathode. The cathode is turned slowly by means of link chains and sprocket wheels of a non-corrosive metal, located between two rows of vats. The cathode is in metallic connection with a slip ring which revolves with it, a brush contact being provided which is connected either to the return lead or to the anode of the next vat.

The solution used in the process contains copper sulphate and a surplus of about 4 per cent free sulphuric acid. At the beginning the vats are filled with this solution almost to the top, so that the cathode cylinder is covered completely.

The tube thus produced is completely finished and does not need any kind of subsequent working. After being cut to the desired length, it is ready to be shipped. It is perfectly straight and truly cylindrical, while both its inner and outer surfaces are quite smooth.

The material of such an electrolytic tube possesses properties that are usually not obtained with ordinary commercial copper. It is particularly remarkable for its toughness. A subsequent mechanical working of the tubes in tube rolling mills or tube drawing benches is employed only in the manufacture of smaller tubes, or if the tubes are to be used for purposes for which great toughness is less important than hardness and resilience. Copper cylinders with a tensile strength of as much as 60,000 lb. per sq. in. can be produced in this way. The toughness of the copper in an electrolytic cylinder is so great that turnings obtained by machining the cylinder in a lathe can be drawn down to the very thinnest of copper wires without having to be previously annealed.

The possibility of producing seamless copper cylinders up to diameters of $8^1/_4$ ft. with any desired wall thickness and of an absolutely cylindrical shape is of great importance for certain industries, especially the textile and paper industries. Experience has shown that welded or soldered seams either disfigure the fabric of the bands of paper, or leave other undesirable traces.

By using cathode cores of low-melting-point metals or alloys it is possible to manufacture any kind of hollow bodies of circular section like conical tubes, corrugated tubes, or tubes with internal flanges. (James Silberstein in *The Metal Industry*, New York, vol. 25, no. 12, Dec., 1927, pp. 487–488, *d*)

CLASSIFICATION OF ARTICLES

Articles appearing in the Survey are classified as *c* comparative; *d* descriptive; *e* experimental; *g* general; *h* historical; *m* mathematical; *p* practical; *s* statistical; *t* theoretical. Articles of especial merit are rated *A* by the reviewer. Opinions expressed are those of the reviewer, not of the Society.

Geographical Location of Bad Condenser-Water Conditions

As Evidenced from Rate of Condenser-Tube Renewals in the United States

(Progress Report of A.S.M.E. Special Research Committee on Condenser Tubes[1])

THE Sub-Committee on Questionnaire—Bert Houghton, Chairman, D. W. R. Morgan, Horace A. Staples—of the A.S.M.E. Special Research Committee on Condenser Tubes has investigated condenser-tube conditions throughout the country with a view to mapping localities according to degree of condenser-tube deterioration. Questionnaires were sent to 858 companies, large and small, throughout the United States, requesting information on the causes, rapidity, and number of condenser-tube failures; the kind of tubes and number in use; the source of circulating water; methods and frequency of cleaning; and the number and frequency of tube replacements.

Replies with data were received from 240 plants. Of these only 141 reported failure of some sort, and the information submitted from the 141 plants was compiled and was presented in tabular form in the Sub-Committee report.

The data submitted by several companies were very complete

TABLE 1 NUMBER OF TUBES IN SERVICE CLASSIFIED AS TO ALLOY, CIRCULATING WATER, AND OUTSIDE DIAMETER

Alloy	Circulating water	Outside diameter	
1,057,435 Admiralty	882,792 tidal waters	1 in.	1,312,204
849,199 Muntz	1,518,103 fresh waters	3/4 in.	117,744
494,261 unclassified		5/8 in.	11,924
		Misc.	959,023
2,400,895	2,400,895		2,400,895

TABLE 2 FREQUENCY OF CLEANING

Intervals	Plants	Per cent
Semi-weekly	11	7.8
Weekly	28	19.9
Semi-monthly	19	13.5
Monthly	28	19.9
Three months	12	8.5
Semi-annually	8	5.6
Annually	9	6.4
Irregularly	17	12.0
No cleaning	9	6.4
Total	141	100.0

TABLE 3 SUMMARY OF FAILURES REPORTED BY 141 PLANTS

	Tubes installed	Replacements: Total	Replacements: Yearly average	Replacements: Per cent	Per cent replacement based on total tubes installed
Corrosion	884,047	660,138	59,255	6.7	2.5
End corrosion	406,451	151,561	16,218	4.0	0.7
Erosion	66,506	44,025	5,935	8.9	0.2
Corrosion and splitting	103,531	33,960	2,710	2.6	0.1
Splitting	804,470	60,284	5,320	0.7	0.2
Scale	48,254	6,348	584	1.2	0.02
Unclassified	87,636	19,207	2,062	2.4	0.08
	2,400,895	981,433	96,593		4.0

PER CENT AVERAGE YEARLY REPLACEMENT WITH GEOGRAPHICAL LOCATION, OMITTING PLANTS THAT DID NOT GIVE FIGURES OF REPLACEMENT

	Tidal waters: Tubes installed	Atlantic Metropolitan	Atlantic (other than Metropolitan)	Gulf	Pacific	Fresh waters: Tubes installed	Pacific drainage area	Great Lakes area	Western drainage area of Miss. R.	Eastern drainage area of Miss. R.	Atlantic drainage area
Corrosion	614,138	10.0	5.1	1.1	11.1	105,400	0.2	9.8	..	..	..
End corrosion	222,178	9.7	2.8	None	None	131,074	None	0.02	10.2	10.2	None
Erosion	19,779	None	9.3	42.5	None	45,352	None	None	1.7	1.8	1.3
Corrosion and splitting	10,740	None	1.9	None	1.3	88,708	None	None	0.3	12.2	6.2
Splitting	4,547	None	None	None	0.04	700,364	0.03	0.2	3.6	None	1.5
Scale	1,632	None	11.9	None	None	32,756	None	None	1.3	2.3	0.3
Replacement	....	11.1	4.5	5.5	10.0	.....	0.1	0.5	None	1.2	None
Unclassified	5,695	..	..	..	..	81,941	..	..	4.4	3.5	1.1
Data incomplete	4,083	..	..	..	..	332,508	..	..	..	..	..
Total	882,792					1,518,103					

[1] The personnel of this Committee is as follows:

Albert E. White, Chairman, Director Department of Engineering Research, University of Michigan, Ann Arbor, Mich.

Paul A. Bancel, Manager, Condenser Department, Ingersoll-Rand Company, New York, N. Y.

R. H. Barber, New Bedford Gas & Edison Light Co., New Bedford, Mass.

Wm. H. Bassett, Technical Supt., The American Brass Company, Waterbury, Conn.

George G. Bell, Manager, Power Development, West Penn Power Co., Pittsburgh, Pa.

Donald K. Crampton, Metallurgist, Chase Metal Works, Waterbury, Conn.

Harvey M. Cushing, Chief Engineer, Buffalo General Elec. & Gas Co., Buffalo, N. Y.

Harold F. Eddy, Mechanical Engineer, Commonwealth Power Corp., Jackson, Mich.

H. B. Hird, Bureau of Engineering, Navy Department, Washington, D. C.

Vincent M. Frost, Asst. to General Supt. of Generation, Public Service Electric and Gas Company, Newark, N. J.

Walter L. Green, Jr., Superintending Engineer, Luckenbach Steamship Co., Inc., Brooklyn, N. Y.

Charles F. Harwood, Manager, Condenser Dept., Worthington Pump & Machinery Corp., New York, N. Y.

Clarence F. Hirshfeld, Chief, Research Dept., Detroit Edison Co., Detroit, Mich.

Bert Houghton, Operating Supt., Edison Illuminating Co., Inc., Brooklyn, N. Y.

Howard W. Leitch, General Supt. of Power Plants, The United Electric Light & Power Co., New York, N. Y.

D. W. R. Morgan, Mgr., Condenser & Internal Combustion Engrg., Westinghouse Electric & Manufacturing Co., South Philadelphia, Pa.

Wm. B. Price, Chief Chemist, Scovill Manufacturing Co., Allentown, Pa.

Norman G. Reinicker, Superintendent of Operation, Penn Power & Light Company, Allentown, Pa.

Horace A. Staples, Vice-President, British American Metals Company, Inc., Plainfield, N. J.

William R. Webster, Vice-President, Bridgeport Brass Company, Bridgeport, Conn.

TABLE 4 TABULATED SUMMARY OF DATA FROM REPLIES TO QUES-

Type of failure	Atlantic Metropolitan Tidal Waters			Atlantic Tidal Waters (Except Metropolitan)			Gulf Tidal Waters			Pacific Tidal Waters		
	Tubes installed	Replacement Yearly avg.	Replacement Per cent	Tubes installed	Replacement Yearly avg.	Replacement Per cent	Tubes installed	Replacement Yearly avg.	Replacement Per cent	Tubes installed	Replacement Yearly avg.	Replacement Per cent
Pitting	58986	7482	12.7	19170	350	1.8	15020	352	2.3	35308	15	0.04
Corrosion	55988	7387	13.2	9707	17	0.2	7868	238	3.0	9555	390	4.1
	15358	805	5.2	49515	4080	8.2	30590	47	0.2	5341	1447	27.1
	32880	2043	6.2	3030	60	2.0	5770	1	0.02	22310	4500	20.2
	23050	2527	11.0	2168	12	0.6	...	..	..	10393	1288	12.4
Dezincification	32104	6777	21.1	2150	474	22.1	...	..	..	14940	3218	21.5
	22242	1594	7.2	12940	1208	9.4	...			...	...	..
	40680	13	0.03	38496	705	1.8	...					
	....	...	..	22300	2043	9.2	...					
	.....	...	..	16279	43	0.3	...					
Total	281288	28628	10.2	175755	8992	5.1	59248	638	1.1	97847	10858	11.1
Corrosion at ends	75387	6898	9.2	1273	33	2.6	...	..	..	...	...	..
	53761	5604	10.4	74757	2443	3.3	...	..	..	...	...	..
Erosion at ends	....	...	..	17000	139	0.8	...	..	..			
	....	...	..	...	...	..	...	..	..			
	.....	...	..	...	...	..	...	..	..			
Total	129148	12502	9.7	93030	2615	2.8						
Erosion	....	...	..	12073	1030	8.5	5582	2370	42.5			
	....	...	..	2124	292	13.8	...	...	..			
Total	.....	...	..	14197	1322	9.3	5582	2370	42.5	....	...	..
	....	...	..	2600	50	1.9	4083	..	..	8140	108	1.3
	....	...	..	...	...	..	...	..	..	...	...	..
	....	...	..	...	...	..	...	..	..	...	...	..
Pitting and splitting	....	...	..	...	...	..	...	..	..	...	...	..
	....	...	..	...	...	..	...	..	..	...	...	..
	....	...	..	...	...	..	...	..	..	...	...	..
Total	....	...	..	2600	50	1.9	4083	..	..	8140	108	1.3
	....	...	..	...	...	..	...	..	..	4547	2	0.04
	....	...	..	...	...	..	...	..	..	...	...	..
	....	...	..	...	...	..	...	..	..			
	....	...	..	...	...	..	...	..	..			
	....	...	..	...	...	..	...	..	..			
	....	...	..	...	...	..	...	..	..			
Splitting	....	...	..	...	...	..	...	..	..			
	....	...	..	...	...	..	...	..	..			
	....	...	..	...	...	..	...	..	..			
	....	...	..	...	...	..	...	..	..			
	....	...	..	...	...	..	...	..	..			
	....	...	..	...	...	..	...	..	..			
Total	....	...	..	...	...	..	...	..	..	4547	2	0.04
	....	...	..	1632	194	11.9	...	..	..	...	...	..
Scale	....	...	..	...	...	..	...	..	..	...	...	..
	.....	...	..	...	...	..	...	..	..	...	...	..
Total	....	...	..	1632	194	11.9	...	..	..	...	...	..
	....	...	..	...	...	..	5695	583	10.2			
Unclassified	....	...	..	...	...	..	...	..	..			
	.....	...	..	...	...	..	...	..	..			
Total	....	...	..	...	...	..	5695	583	10.2	....	...	..
GRAND TOTAL	410436	41130	10.0	287214	13173	4.6	74608	3591	4.8	110534	10968	9.9

in every detail, and in some cases included records of tube replacements and failures for the last twenty years. Generally, however, the data were not complete. The figures of tube replacements were the most definite and were worked up on an average yearly percentage replacement basis for each station. The result should therefore indicate the relative degree of tube failures from the various localities reporting.

The following summaries have been made from the report submitted to the committee on Dec. 6, copies of which can be secured on application to the Society.

There were 52 different classifications for cause of failure, indicating the necessity for standardizing the nomenclature in reporting failures.

The Committee in making the summaries endeavored to interpret the data in order to reduce the number of classifications, as in many cases there was a difference in the language used to describe the same type of failure. Where doubt existed in any given case it was placed in the unclassified section.

No attempt was made to separate the alloys, but in general where circulating water was active as an electrolyte, Admiralty was used, and where the circulating water was good, Muntz metal was generally employed.

The percentage of Admiralty alloy tubes, based on 1,906,634 tubes in service, was 55½. The percentage of tubes in service in tidal waters was 36.9. It was possible to classify as to diameter 1,441,872 tubes, and of these 91.1 per cent were 1 in. in diameter.

Cleaning. The most common method of cleaning employed is by shooting metal, metal and canvas, rubber, or rubber and canvas plugs through the tubes by air or water under pressure. In cases where the deposit on the tubes is of an oily or very slimy nature these methods are not quite successful in completely cleaning the tubes, in which cases a more rigorous cleaning is given annually or semi-annually by sandblasting or using wire brushes. In cases where extremely hard deposits of scale are met, acid treatment, turbining, or drilling out of the scale with power drills is resorted to.

Coastal Section. Stations on the seaboard report bad water conditions varying from natural to highly polluted water near the large cities. Tube replacements are heavy throughout this section. Of forty-one stations reporting, five had average yearly replacements in excess of 20 per cent and one had replacements of over 30 per cent. The averages were 11.1 for the Metropolitan area; 4.5 for the Atlantic Coast other than Metropolitan; 5.5 for the Gulf Section, and 10.0 for the Pacific Coast.

Great Lakes Section. Of twenty-one stations from the Great Lakes Section, three reported average yearly replacements of over 1 per cent, and nine reported negligent failures. East Chicago has serious trouble from corrosion and erosion, and reports the highest percentage of tube replacements in this

TIONNAIRE OF A.S.M.E. COMMITTEE ON CONDENSER-TUBE RESEARCH

Western Fresh Waters (Pacific Drainage Area) Replacement			Great Lakes Waters Replacement			Mississippi River — Western Drainage Area Replacement			Mississippi River — Eastern Drainage Area Replacement			Eastern Fresh Waters (Atlantic Drainage Area) Replacement		
Tubes installed	Yearly avg.	Per cent	Tubes installed	Yearly avg.	Per cent	Tubes installed	Yearly avg.	Per cent	Tubes installed	Yearly avg.	Per cent	Tubes installed	Yearly avg.	Per cent
6000	13	0.2	2592	42	1.6	8565			4115	406	9.9			
			44800			970	194	20.0	61560					
			11234	1308	11.7		3		44700					
						15000	5097	34.0	5906	42	0.7			
						17862	404	2.3	1255	126	10.0			
						19644	407	2.1	14370	2080	14.5			
						6452	17	0.3	4884					
6000	13	0.2	58626	1350	2.3	68493	6122	8.9	136790	2654	1.9			
			60724	72	0.1	1780	30	1.7	14298	20	0.1	31541	408	1.3
			9200	95	1.0				3183	455	14.3	18955		
			7975						5430	19	0.3			
									26269					
									4918	2	0.04			
			77899	167	0.22	1780	30	1.7	54098	496	0.9	50496	408	0.8
						3150	2	0.1	6450	916	14.2	1153	713	6.2
						1375			5600	560	10.0			
						18622	52	0.3						
						23147	54	0.2	12050	1476	12.2	11530	713	6.2
						11473	684	6.0				28638	417	1.5
						13586	670	4.9						
						10685	577	5.4						
						24326	204	0.8						
							2							
						60070	2137	3.6				28638	417	1.5
6440	2	0.03	59690	250	0.4	7900	3		9300	3	0.03		10	
			48155	72	0.2	3596			5690	31	0.6	3985	1	0.03
			27416	150	0.6	1900	2	0.11	12400	24	0.2	4440		
			54896	32	0.06	5200	186	3.6	460	10	2.2	5228	1	0.02
			63724	18	0.03				2500	20	0.8	11806	7	0.06
			12890			6110	84	1.4	47800	6	0.01	5344		
			38590						24000	3	0.01	5600	38	0.7
			100040	331	0.3							20491	4	0.02
			9100						4200			7281	16	0.2
			13399						2400	19	0.8	8000		
									57516	3586	6.2	35276	111	0.3
												54564	146	0.3
												12596	152	1.2
6440	2	0.03	427900	853	0.2	24706	275	1.1	166266	3702	2.2	174611	486	0.3
						1656			3176	194	6.1			
									29580	196	0.7			
									12210					
						1656			44966	390	0.9			
			26940	1		15442	7	0.05	14777	94	0.6	9040	600	6.6
						4303	11	0.3	3439	766	22.3			
									8000					
			26940	1		19745	18	0.1	26216	860	3.2	9040	600	6.6
12440	15	0.1	591365	2371	0.4	199597	8636	4.3	440386	9578	2.2	274315	2624	1.0

section, i.e., 11.65 per cent. The replacements for the entire section, as reported, was 0.5 per cent.

Mississippi Valley Section. Of thirty-eight stations reporting six have average yearly replacements of over 1 per cent, and five (have over 10 per cent. Nearly all the companies reporting high replacements are located in the manufacturing districts on the Ohio River and its tributaries. The type of failure in these districts include corrosion, erosion, and dezincification. The average percentage of replacements of this section are 4.4 per cent on the West Side and 3.5 per cent on the East Side.

The Sub-Committee was continued and directed to make a study and investigation of the data submitted, for the purpose of rendering a second report with recommendations.

Correspondence

CONTRIBUTIONS to the Correspondence Department of Mechanical Engineering are solicited. Contributions particularly welcomed are discussions of papers published in this journal, brief articles of current interest to mechanical engineers, or comments from members of The American Society of Mechanical Engineers on its activities or policies in Research and Standardization.

A Steam-Pressure Transformer

TO THE EDITOR:

There is an error in the article entitled "A Steam-Pressure Transformer" which appeared in MECHANICAL ENGINEERING for June, 1927. The equation on the second line of the second column of page 601 should be $h_0 = h - \Delta h + L_0$, where Δh is the difference between the sensible heat of water at the temperature in B and the temperature of steam entering B. In the original article Δh is omitted.

With this correction columns 7–10 of Table 1 and column 8 of Table 2 are changed to the following values:

TABLE 1				TABLE 2
(7)	(8)	(9)	(10)	(8)
1.312	1.937	1.194	1.206	0.653
1.236	1.629	1.373	1.374	0.698
1.174	1.423	1.528	1.523	0.740
1.123	1.279	1.659	1.652	0.752
1.097	1.242	1.688	1.682	0.818
1.073	1.186	1.748	1.742	0.850

LIONEL S. MARKS.[1]

[1] Professor of Mechanical Engineering, Harvard University, Cambridge, Mass. Mem. A.S.M.E.

Engineering and Industrial Standardization

The A.E.S.C. Further Develops Its Procedure

FOR MORE than a year the enlarged Rules Committee of the American Engineering Standards Committee has been at work on a revision of its Rules of Procedure originally drafted at the time of the Committee's organization in 1918. During the past six months it has been assisted by a group of members of the A.E.S.C. having a major interest in its work but not regularly members of the Rules Committee.

The report of this enlarged Committee was distributed to the members of the A.E.S.C. Executive Committee on November 7, 1927, and it was informally discussed at a meeting of the latter on November 10. Then on December 8 at the Annual Meeting of the Main Committee the report came up for full discussion. After which it was ordered to letter-ballot. This ballot was completed early in January, so the A.E.S.C. is now functioning under a new and considerably broadened procedure. The first five paragraphs of the new document convey very well the spirit of the whole, so they are quoted below in full.

101 A national standard implies a consensus of those substantially concerned with its scope and provisions. A chief function of the A.E.S.C. is the judicial one of determining whether a national consensus has been reached. To provide flexibility in meeting the variety of conditions which obtain in standardization work, several alternative methods are provided. The basic test to be applied in all cases is the fact of the assent, affirmatively expressed, of the groups having substantial interest in the standard. Such groups have an inherent right to representation on the body dealing with the subject matter of the standard, but it is not essential that this right be exercised.

102 Standards may come before the A.E.S.C. for approval by any method that provides compliance with the requirements stated in Sec. 101; the following methods are recognized:

(*a*) *Sectional Committee Method.* This method consists in the formation, at the beginning of a project, of a committee to make a standard, or many standards under an assigned scope, which is composed of representatives accredited for the purpose by the various organized groups concerned with the project.

Sectional Committees may be established under two systems of administrative control, as follows:

(I) Under the administrative support and direction of one or more of the bodies principally concerned. Such bodies are known as Sponsors.

(II) They may function autonomously with certain limitations.

(*b*) *Existing-Standards Methods.* Existing standards may be approved by the A.E.S.C., provided it is shown that the standard is supported by a consensus of those substantially concerned with its scope and provisions.

(*c*) *Proprietary-Standards Method.* A proprietary standard is defined as one made under the auspices of an organization occupying an outstanding position in the field of the standard and where the formulation of the standard, in the first instance and in its revisions, is done within the organization. Standards of this type may be approved by the A.E.S.C. when it is shown that they are supported by a consensus of those substantially concerned with their scope and provisions.

(*d*) *General-Acceptance Method.* This method consists in the establishment of the necessary consensus by a canvass, ordinarily by correspondence, of those substantially concerned with the scope and provisions of the proposed standard.

103 To safeguard the judicial character of its approval, the A.E.S.C. requires that projects coming before it for consideration shall be sponsored by one or more bodies competent to vouch for the technical qualifications of a standard.

A sponsor is such a body recognized by the A.E.S.C. as an advocate of a standard or a group of standards.

(*a*) An Administrative Sponsor is one which exercises administrative support and control over a Sectional Committee.

(*b*) An Endorsing Sponsor is one which recommends entering upon, and/or the final endorsement of, a project assigned to an Autonomous Sectional Committee or a project undertaken by the General Acceptance Method.

(*c*) A Proprietary Sponsor is one which produces proprietary standards within its own organization.

104 A sponsor need not be a member-body. Two or more bodies may be designated as Joint Sponsors.

105 Administrative or Proprietary Sponsorships entail the responsibility, on behalf of the committees engaged in making standards, of:

(*a*) Causing the work to be prosecuted with due diligence.

(*b*) Providing for the publication of standards.

(*c*) Providing for the administrative work and the facilities necessary thereto, including secretarial services.

Recent Activities of the Division of Simplified Practice

PRELIMINARY, general, and revision conferences have recently been held under the auspices of the Division of Simplified Practice, U. S. Department of Commerce, looking to the simplification of:

Paint and Varnish Brushes[1]	Boxboard Thicknesses[2]
Steel Barrels and Drums	Folding Chairs
Hollow Metal and Kalamein Doors	Composition Books
Surveying Instruments	Adhesive Plaster
Cheese and Cheese Containers	Pocket Knives
Hospital Plumbing Fixtures	Marine Hardware
Polishing and Buffing Wheels	Beekeepers Supplies
Panelboards and Switchboards	Glass Containers

Household and Industrial Brushes.

NEW A.E.S.C. STANDARDS

The following standards were approved by the A.E.S.C. during the months of December, 1927, and January, 1928:

"The Code for the Design of Transmission Shafting" (Tentative American Standard). Published by A.S.M.E.

"The Safety Code for Mechanical Power Transmission Apparatus"—First Revision (American Standard). Published by A.S.M.E.

"Malleable Iron Screwed Fittings—For maximum working saturated steam pressure of 150 lb. per sq. in. (Gage)" (Tentative American Standard). Published by A.S.M.E.

"Cast Iron Screwed Fittings—For maximum working saturated steam pressures of 125 and 250 lb. per sq. in. (Gage)" (Tentative American Standard). Published by A.S.M.E.

"Safety Code of Colors for Traffic Signals" (American Standard). Published by Bureau of Standards.

"Methods of Testing Wood"—(a) Standard Methods of Testing Small Clear Specimens of Timber; (b) Standard Methods of Conducting Static Tests of Timbers in Structural Sizes. (American Standard.) Published by American Society for Testing Materials.

"Rating Section" of "Standards for Induction Motors and Induction Machines in General" (American Standard). Published by American Institute of Electrical Engineers.

[1] Revision. [2] Reaffirmation.

The Conference Table

THIS Department is intended to afford individual members of the Society an opportunity to exchange experience and information with other members. It is to be understood, however, that questions which should properly be referred to a consulting engineer will not be handled in this department.

Inquiries will be welcomed at Society headquarters, where they will be referred to representatives of the various Professional Divisions of the Society for consideration. Replies are solicited from all members having experience with the questions indicated. Replies should be as brief as possible. Among those who have consented to assist in this work are the following:

ARCHIBALD BLACK,
Aeronautic Division
A. L. KIMBALL, JR.,
Applied Mechanics Division
H. W. BROOKS,
Fuels Division
R. L. DAUGHERTY,
Hydraulic Division
WM. W. MACON,
Iron and Steel Division
JAMES A. HALL,
Machine-Shop Practice Division
CHARLES W. BEESE,
Management Division
G. E. HAGEMANN,
Materials Handling Division
J. L. WALSH,
National Defense Division
L. H. MORRISON,
Oil and Gas Power Division
W. R. ECKERT,
Petroleum Division
F. M. GIBSON and W. M. KEENAN,
Power Division
WINFIELD S. HUSON,
Printing Industries Division
MARION B. RICHARDSON,
Railroad Division
JAMES W. COX, JR.,
Textile Division
WM. BRAID WHITE,
Wood Industries Division

Applied Mechanics

Courses in Applied Mechanics[1]

AM-2 Are advanced courses in Applied Mechanics, particularly in Dynamics, needed?

The writer has read with interest in the December, 1927, issue of MECHANICAL ENGINEERING, the discussion by G. B. Karelitz and agrees with most of what he says. In the writer's opinion he is right in stating that our technical schools will find it advisable and necessary to offer advanced courses in both Strength of Materials and Dynamics. Such courses have been offered at Purdue University for several years. A.M. 101 is Advanced Strength of Materials, and A.M. 102 is Advanced Statics and Kinetics. These courses are open both to undergraduates and graduates. The six men now taking A.M. 101 are all seniors who have elected this course as a technical option. Mr. Karelitz, no doubt, would agree that these advanced courses should not be made part of the required curriculum, but should be open to election by undergraduates who are interested and properly prepared to take such courses. The outline which Mr. Karelitz gives under his course in Advanced Dynamics covers almost the same ground that A.M. 102 does, with the following exceptions: first, the principle of virtual displacement is not used to any extent in solving problems in statics as it is the writer's belief that there are other methods better adapted to the ordinary student; second, some time is given to further discussion of methods of work and energy as applied to machines. Mr. Karelitz does not mention this in his program. The writer regards Purdue's course A.M. 101 to be fully as valuable as A.M. 102. However, it probably makes a greater appeal to students in Civil Engineering than to those in Mechanical Engineering. Mr. Karelitz appears to be right in urging that these courses be presented from the engineering standpoint rather than from the mathematical. Our engineering students need to have the application impressed upon them. However, it is the writer's belief that the fundamental mathematical principles should be thoroughly developed and the reasoning processes underlying them should be mastered. (R. G. Dukes, Head, Dept. of Applied Mechanics, Purdue University.)

[1] This subject has been discussed in a previous issue.

Iron and Steel

Pearlitic Cast Iron

IS-1 What is pearlitic cast iron, about which so much is written abroad?

Pearlitic cast iron was invented by Diefenthaler at the Lanz foundry in Germany and is an iron which is of such a composition that if cast in an ordinary mold would give a wide fracture. Through being cast, however, in a mold heated to a certain temperature and through having therefore the cooling of the metal retarded in a certain manner, a microstructure is produced which consists of a pearlite matrix with enclosures of free graphite and which therefore gives a metal of superior strength. Pearlitic cast iron has a low silicon and low total-carbon content, the temperature of the mold depending on these two factors of composition and the thickness of the section. This temperature may vary from about 100 deg. for thick sections to, say, 200 deg. cent. (392 deg. fahr.) for thin sections. The most general composition appears to be: total-carbon content, 3 per cent—including graphite around 2.15 per cent—and silicon 1 per cent. In Europe the new iron has attracted particular attention in England where a number of foundrymen have taken out licenses under the German patents. For further information see the reference in Principles of Metallurgy of Ferrous Metals, by Leon Cammen, 3rd edition, p. 124, published by the A.S.M.E. (EDITOR.)

Questions to Which Answers Are Solicited

Factory Location

MG-1 What are the relative advantages of a factory located in the center of distribution vs. smaller factories located in different parts of the country? This refers to a company manufacturing one product and having a national distribution of that product?

Stresses in Oil-Well Casings

PT-1 What methods are recommended for determining the types of stresses causing failure of oil-well casings at depths of 2000 to 3000 ft.?

Status of Compound Locomotive

R-1 What is the status of the compound locomotive today in view of rising steam pressures and fuel costs?

Maximum Boiler Pressure in Simple-Cylinder Locomotives

R-2 What is the maximum boiler pressure that can be economically used in simple-cylinder locomotives?

MECHANICAL ENGINEERING

A Monthly Journal Containing a Review of Progress and Attainments in Mechanical Engineering and Related Fields, The Engineering Index (of current engineering literature), together with a Summary of the Activities, Papers and Proceedings of

The American Society of Mechanical Engineers

29 West 39th Street, New York

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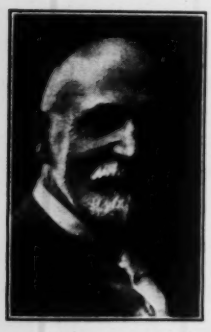
Contributions of interest to the profession are solicited. Communications should be addressed to the Editor.

BY-LAW: The Society shall not be responsible for statements or opinions advanced in papers or.... printed in its publications (B2, Par. 3).

The Relation Between Industry and Taxation



ALEX DOW

THE attitude of Prof. T. S. Adams as set forth in his lecture at the Annual Meeting in December is somewhat pessimistic in the expression of his belief that industry will have to carry heavier burdens of taxation and that the rising tide of public expenditures cannot be checked.

Professor Adams has directed his discussion almost exclusively to the incidences of Federal taxation. So long as every group of well-meaning persons and each society for the betterment of mankind will go to Washington expecting or demanding that the United States act as fairy godmother to ideas which are merely stepchildren in the households of the states or municipalities, just so long will the burden of Federal taxation continue to pile up. If and when, however, there comes the desirable (and, I think, inevitable) reaction toward strict construction, it will become possible for the Federal Government to restrict its activities to those things which are contemplated by our basic charter—the United States Constitution.

I have said it will be possible. There will remain with us the inertia of Government departments which have no mind to cease the activities excusing their existence, and the indisposition of Congresses to expend any amount less than the available funds—so we need not hope to realize all of the possibilities of economy.

I never saw economy yet that was realized excepting by doing without things that were desirable. The necessities of life, and the conveniences of life, and the amenities of life, are altogether less than the desires of us mortals. If our tax-expanding powers or our appropriating bodies throughout the country will confine themselves to commitments for all things necessary, and for a few convenient things, and for enough of the amenities to prevent a rich nation from assuming an appearance of poverty, there will remain a large saving. In other words, we can do very nicely indeed without a lot of "fuss and feathers" for which public money is now appropriated and spent.

One point which Professor Adams has not made, but which is very much in order, is that taxation upon industry is likely to become indirect taxation upon the ultimate consumer. There is very little fault to be found with a tax which appropriates a reasonable amount of demonstrable profits. If one really has the profits one has no call to grumble about the tax. Some grumbling is desirable, so long as it is an indication of a spirit which will express itself in efforts to control needless expenditures of taxes. As Professor Adams points out, we expend our energy in grumbling and not in effective work toward betterment. So long as the country is fairly prosperous, that is exactly what will happen. Some day, without having hard times, we shall have narrow margins of profit and we shall have to insist that we be not taxed for needless occasions, and that all the money collected shall be economically spent. When that day arrives the fact that any particular tax is a direct burden will be helpful. The man who pays a surtax upon an automobile which he purchases, or upon the gasoline he uses for the filling of the automobile tank, knows that he is paying a tax, and he is likely in that coming day to ask where the money goes. Conversely, the man who makes an unrecognized tax payment in an additional five, ten, or fifteen per cent of the price which he pays for necessities or comforts of his daily life, is inclined to blame the merchant or the manufacturer. He does not see the tax, but it is there just the same.

As engineers we do not fully realize how much of the selling price of our output is diverted into public uses, and the purchasers of our output do not realize it at all. When the day of strict economies arrives it will be well for us if we have educated the ultimate consumer so that he will recognize not only his direct taxes, but likewise the taxes which strike his pocketbook by indirection or by circumlocution.

ALEX DOW.

One Thing the A.S.M.E. Has Left Undone

IT IS A SAD fact that the Society has not driven home to the membership at large the conviction that an engineer has only half finished his job when he has written a paper which is novel, accurate, and of technical value and interest. He still has the responsibility of putting himself and his message across at the meeting. He must "sell" himself to his audience.

The Meetings and Program Committee members hold themselves responsible for this situation and have been asking themselves, "What is the cure for this infirmity?" A consultation was held and the doctors decided on a new treatment.

The authors for the Annual Meeting in New York were asked whether, at no cost to themselves other than mental anguish, they wished to run the gauntlet of constructive criticism at the hands of a professional public-speaking coach. Over half of them "chose to run."

The Committee engaged a coach and the clinic was on. The head surgeon was handicapped by a lack of experience in engineering meetings, but he threw himself into the task and performed several successful operations. He cut out a few inferiority complexes more or less completely. He entirely re-

moved several "I-have-to-read-it-verbatim" complexes. The operations were all performed with no other anesthetic than the engaging personality and sincerity of the surgeon, and the patients all lived through the ordeal. They were under observation at the meetings, and we think their performance justifies further development of the treatment.

Our Society is fortunate in having among its members many a man whose name on the program insures a large and satisfied audience. But there are others.

The clinic will have its second session next December.

Do you see a better way to evolve a race of public speakers?

G. M. EATON.[1]

Educating Industry in Munitions Manufacture

THE United States has gone far in plans for the mobilization of industry in the event of a national emergency. There is still much to be done, and in that the members of this Society are interested as citizens and as engineers. The Society has a National Defense Division in which every American member is automatically registered.

The Secretary of War has recently requested Congress for legislation permitting the placing of educational orders for the making of munitions in industrial plants. His request was supported by the A.S.M.E. Council at its Washington meeting on January 10, upon the recommendation of the National Defense Division, and the American Engineering Council was urged to similarly support Secretary Davis in his effort. The recommendation comes as the result of continued study by the War Department, and a brief review of the developments of the past seven years is therefore important.

Bryan has been quoted as saying that in event of attack the citizens of this country would spring to arms over night. That statement is true if amended to read "spring to broomsticks in six months." It was the lesson of our last experience that men can be recruited and trained many months before they can be equipped. This lesson resulted in the National Defense Act of 1920, which among other things provided an Assistant Secretary of War with the immediate responsibility of providing equipment and munitions for the army. The successive holders of this new office have completed the preliminary plans. Possibilities of conflict between the procuring branches of the War Department have been reduced, emergency requirements have been established, production programs have been prepared, procurement districts have been set up to decentralize the procurement work from Washington, and individual manufacturers have prepared plans showing machinery, tools, gages, etc. that may be required for emergency production. The next step is to actually use this organization that has been set up. Reserve officers and manufacturers have been going through the cycle of procurement and production in pantomime. They should actually try out their plans and produce munitions material, otherwise the smooth functioning of this splendid scheme cannot be assured. The request of the Secretary of War is logical and important if industry is to do its part in a national emergency.

Our Changing Concepts of Matter

IN PHYSICS as in all exact sciences, definitions, theories, and classifications are based merely on the existing state of knowledge. A physicist should be and usually is prepared cheerfully to throw away any theory as soon as facts show that it is not correct, or change his definitions when the progress of science makes it necessary. Just because a thing has been believed to be true for a hundred years does not entitle it to any consideration in the face of new knowledge.

Several instances of this kind may be cited. The distinction between crystalline and amorphous materials is a very old one. Recently as a result of the work of Beilby and Zay Jeffries it has acquired considerable importance in metallurgy, it being believed that metals consist of crystals held together by an amorphous intercrystalline cement. There was from the beginning something suspicious about this theory, as at room temperature the intercrystalline cement was supposed to be actually stronger than the crystalline material. Usually amorphous matter is supposed to be brittle and lacking in mechanical strength, particularly the ability to resist shock.

However, that had to be accepted because the microscope showed it to be so. The same distinction between amorphous and crystalline matter permeated the whole of physics, organic matter being usually considered as amorphous. (The word "organic" is here used not in the chemical but in the biological sense.)

As further investigation proceeded, however, and methods were developed which permitted finer observation, this theory gradually began to crumble, at least in its major applications. First it was discovered that the so-called amorphous carbon is not amorphous at all, but consists of very fine crystals. This will probably not prevent its being called amorphous for the next generation, however. It was next discovered that certain colloids are also crystalline, so that the distinction between crystalline and colloid solutions, while remaining essentially correct in its meaning, is certainly one most improperly described in its terminology. Finally it was discovered that materials in which crystalline structure was not only unsuspected but would have been vigorously denied in the past, are really crystalline. Thus natural rubber has been found by Professor Katz of the University of Amsterdam to consist of very minute crystals and this discovery may explain the reason for rubber's remarkable elasticity and also the secret of the failure of rubber artificially produced from isoprene to measure up in this respect to the natural product. The difference between the latex-coagulated rubber and the rubber permitted to coagulate on the trunk will probably also be ultimately traced to the same cause.

Another instance deals with the state of matter. For many generations physicists have taught that there are three states of matter—solid, liquid, and gaseous, while it has been one of the fundamental principles of hydraulics that liquids have no tensile strength, or that their tensile strength, if any, may be considered as negligible. Recent observation on films has, however, shown that here are liquids which unquestionably possess a tensile strength of a very high order. If it were not so, lubrication would be impossible.

It may also be news to the engineer to learn that water is not the simple liquid that he thought it was. Chemists have for a long time been studying this liquid, and as far back as in 1910 at a symposium held by the Faraday Society in London, Bousefield and Lowry suggested that water is a ternary mixture composed at low temperatures of $(H_2O)_3$ and $(H_2O)_2$, but at higher temperatures of $(H_2O)_2$ and $(H_2O)_1$. Previous work by Röntgen, Whiting, Sutherland, and others indicated that water instead of being a simple liquid is a very complex one. Thus Röntgen claimed that water is a saturated solution of ice molecules, with a concentration depending on the temperature, a decrease in temperature favoring the formation of more complex ice molecules. This presence of ice molecules in liquid water would, by the way, explain the rather peculiar fact that water reaches its

[1] Member of A.S.M.E. Standing Committee on Meetings and Program.

maximum density at a temperature of about 4 deg. cent. On the other hand, H. E. Armstrong believes that water is a complex mixture saturated with a "gas" hydrone (OH_2) which may become active under the influence of a dissolved substance. According to Tammann, the fact that water reaches a minimum volume at 4 deg. cent. can be explained by the presence of molecules of greater volume which increase in concentration as the temperature is decreased.

A still more marvelous vista is opened by the application of X-ray analysis to the study of liquid water. All of this is of interest to the mechanical engineer, because certain thermodynamic phenomena will be apparently explainable by a better knowledge of the structure of water. Furthermore, its structure affects the behavior of water at high pressures, as has been already shown, for example, by Röntgen, who found that the thermal coefficient of expansion of water at pressures of 3000 atmos. and over increases with increase in pressure, which is contrary to what happens with other liquids. Engineers have not yet come to use such pressures, but pressures of several thousand pounds are already used and higher ones are in sight. The matter of corrosion, particularly corrosion by very pure water, is also probably involved in the subject of the molecular structure of water.

Post-Collegiate Education

ELSEWHERE in this issue is published a thought-provoking address delivered at the Annual Meeting of the Society by W. E. Wickenden, Director of Investigation of the Society for the Promotion of Engineering Education. This straightforward exposition of the part the engineering societies can play in engineering education concludes with a summary of active measures which are recommended as a basis for procedure by the societies. As Mr. Wickenden takes pains to point out, ample precedent can be found for his plan of action, and the desirability of it seems to be substantiated by facts and the opinions of representative engineers as obtained through the medium of questionnaires. Readers who did not have the opportunity of hearing this address should lose no time in examining it, and all engineers should give careful and active consideration to its suggestions.

Without reviewing or commenting on all of the ideas contained in this address, attention is particularly called to the single phase of post-collegiate education as a fruitful field as well as a definite responsibility of the Society toward its members and the profession as a whole.

The machinery is established by means of which students in engineering schools affiliate themselves with the engineering societies through the medium of the student branch, and provision is made for inducting student-branch members into the Society as junior members as soon as graduation marks the termination of academic and the commencement of professional careers. This is commendable, for from what other source will the Society draw such a great number of desirable potential members as from the engineering colleges? The Society, however, has an obligation toward these junior members which Mr. Wickenden recognizes in the seventh item of his summary: "Take a large share in directing the after-college education of young engineers."

The present educational activities of the Society—its publications and its meetings—are available to the younger members. The lists of speakers and contributors to the publications contain the names of a great many young men, but it is not these men we are particularly concerned about. Circumstances and natural gifts have guided these men through that dangerous period of their careers. They are going forward. And there are others, still younger men, who are taking the admirable apprentice courses offered by our great industries. These, too, are finding themselves intellectually and professionally. But to a greater number intellectual and professional stimuli are lacking, and in a few years many who have spent much money and time and hardship in laying the foundation for a career in engineering will find no superstructure upon it, and the foundation itself decayed.

Many an older engineer today, as he thumbs through the pages of Mechanical Engineering, will, if he is honest with himself, regret that he has not kept pace with science and engineering which have progressed more rapidly than he has, and that between the textbook knowledge of his student days and the practice of today there is such a huge and hazy hiatus.

Systematic education for the engineer, even of a meager sort, should continue throughout his career. The press of other affairs will be made an excuse by many, but laziness and indifference are responsible for much lack of attention to the educational advancement of the practicing engineer and his younger brother.

Possibilities of Hydraulic Feed

JUST enough was seen of hydraulic feeds at the Cleveland Machine Tool Exhibit to arouse the curiosity of builders and users of machine tools and to give them a keen desire for more information. The session devoted to this subject at the Annual Meeting of the A.S.M.E. was therefore timely. Enough was told there to bring conviction that in hydraulic feeds lie possibilities of really revolutionary changes in machine-tool design and performance.

It may be too early to predict definitely what these changes will be, but it is almost certain that increased cutting speeds and feeds will result with the same cutting tools which have reached their top limit under conditions of mechanical feed. Ample demonstration of this was made at Cleveland, and frequent references were made to such results in the Meeting papers and discussions—without any very definite explanation being given as to why.

Among the theories advanced was one that the pulsations of the pumping mechanism give a sort of chipping-hammer action to the tools, which gives them freer cutting action. Another reason advanced is that there is a certain solidity to the hydraulic mechanism which holds the tools more rigidly up to their work. Research inspired by the Hydraulic-Feed Session will very likely get to the bottom of this "mystery" in the near future, and will enable these desirable characteristics to be amplified and full advantage taken of them.

In the meantime it is probable that an entirely new set of values will have to be determined for the speeds and feeds of standard cutting tools, such as twist drills and turners, when under the influence of hydraulic feed. Here is a project which vitally concerns both the builders of machine tools and the manufacturers of cutting tools, as an increasing demand for such information already plainly indicates.

The carrying out of this project should be a very interesting piece of work to an organization with the necessary facilities, and the resulting data will be an outstanding contribution to the art of cutting metals.

Submarine Salvage and Safety

THE circumstances attending the sinking and attempted rescue of the submarine S-4 off Provincetown have attracted an unusual amount of attention throughout the country. Many members of the Society have written to its headquarters asking whether anything could have been done to prevent this horror or save the six men who remained alive after the sinking.

As a Naval Court of Inquiry is sitting at this time it is not considered desirable to express any opinion on the happening before all the facts are officially developed. At the same time a staff

article has been prepared and is published in this issue. This article attempts to present in a general form what might be called the present state of the art with respect to submarine safety and salvage, and describes with brief comments the various devices that have been proposed and used for this purpose.

One of the most important conclusions which can be drawn from the facts thus presented is that submarine safety, especially in peace time, can be materially increased over what it is today. But to do this will require a sincere and systematic effort which will involve a serious expenditure of time and money. Above all, the responsibility for the use of safety devices must be concentrated in the hands of one bureau or one person in the various districts, so as to make the responsibility for failure to use the devices clear and unmistakable.

Warfare of the Future

METHODS of warfare are changing as rapidly as everything else in the modern world. There has existed an age-old naval problem which, from a modern point of view, is a problem of antiquity, namely, that of the impenetrable armor and the irresistible projectile. This problem is now superseded by the problem of the airplane that can safely bomb anything and the anti-aircraft apparatus that makes all aircraft futile. Practical work on both sides of this problem is in active progress by both the Army and the Navy. Partisans of various types have sprung up in military, naval, and civilian circles. All seem to generally admit that bombing aircraft, as well as aircraft devoted to reconnaissance, scouting, pursuit, and other purposes, will take an important part in future military and naval operations. It also seems to be generally conceded that an efficient aircraft defense will be an important part of defensive operations against the offense of enemy aircraft. From this point on there seems to be a great divergence of opinion. Those who have spent their lives in the type of warfare which has existed in the past seem to think that it will continue to be a major matter and that the part played by aircraft will be comparatively small, so that a relatively minor equipment of anti-aircraft apparatus, as well as some defensive aircraft, will provide all the defense that is necessary. A directly opposite position is taken by extreme aircraft enthusiasts. These hold that any anti-aircraft apparatus whatsoever is futile, because bombs can be dropped and observations can be made at altitudes from 15,000 to 30,000 ft., where no conceivable anti-aircraft apparatus can interfere. They admit that anti-aircraft apparatus could, perhaps, keep bombers away from regions up to 5000 or 10,000 ft. altitude, but declare that this would be no hardship, inasmuch as bombs can be easily dropped from regions which anti-aircraft apparatus cannot reach. If this be true, the only effective defense against aircraft is other aircraft. These enthusiasts also declare that previously known methods of warfare, such as the use of large guns, afloat and ashore, will be wholly superseded and that practically all warfare will be conducted by bombers and other types of aircraft. Whether they are right, time only can tell. If they can prove their contentions, an increasing percentage of military and naval appropriations will be expended for aircraft, and the percentages spent for the items which up to now have been in the majority will successively decrease.

Research by A.S.M.E. Committee Method

IF IT IS granted that modern industry needs engineering research to enable it to hold its marvelous gains and to point the way to new and greater developments, then it is natural for us to inquire concerning the opportunities and obligations of the national engineering societies in this field.

As the A.S.M.E. grew in numbers and influence it was quite natural for it to respond to the increasing demand of its members for investigations and researches in the field of mechanical engineering and its allied industries. In the early days these were more or less bibliographical. But soon definite problems arose which required experimental work and scientific analysis and study, and in a perfectly normal way these were taken up by committees of the Society's members and other interested persons. In this way the Society's present research activities were evolved from those first simple beginnings.

Under the guidance of the Main Research Committee appointed by the Council in 1909, the Special Research Committees of the Society have assisted materially in the advancement of mechanical engineering and its allied arts. Gradually the activities of these groups have crystallized and certain definite functions have been evolved such as (*a*) serving as clearing houses for the dissemination of research information; (*b*) coordinating existing research work where possible, thus eliminating waste due to the duplication of effort; (*c*) supporting existing research where advisable; and (*d*) organizing and conducting cooperative research work on problems of both a fundamental and applied nature in engineering and industry.

While this committee method as a means for carrying on research has certain definite and serious limitations, it has many strong points. Functioning as they do under the auspices of the Society, these committees are unaffected by commercial considerations of any kind. Their members are technical men interested primarily in the advancement of knowledge of mechanical engineering and of their profession. As far as it is humanly possible, therefore, the results of their work are free from bias of any kind.

Engineering Index Service

AMERICAN industry and engineering put to use the results of scientific investigation nearly as rapidly as they are made known. There appears to be a suction chamber of demand, with industry at the outlet and science at the inlet. On January 3 a catalyzing agent between the supply and the demand for new information appeared in the form of the Engineering Index Service. The American Society of Mechanical Engineers has assumed the sponsorship for this far-reaching service which provides its users with immediate information concerning the articles published in the technical press of the world. The superb resources of the United Engineering Societies' Library are at the command of the Index Staff in the preparation of the material.

The A.S.M.E. Council authorized the Index Service early in October and from that time until the first of the year tremendous efforts were expended in organizing the new staff, housing it, purchasing the mechanical equipment to print the index cards quickly and in placing the service at the command of industry. Industry has responded as it has had opportunity. The first and most difficult task has been the establishment of a master list of subject headings under which the articles appearing in the press will be indexed. The list embodies 25,000 items, which have been secured from a comparison with all available existing classifications. Engineering at large has been divided under 13 main classifications and 118 sub-classifications, affording great flexibility for selection of items of particular interest to the research engineer, the smaller or limited industry, or the largest industry.

A Correction

On page 1312 of the December, 1927, issue of MECHANICAL ENGINEERING the word "light" in the twelfth line of the first column should read "lag."

A.A.A.S. Meets in Nashville

Engineering Sessions Featured by Papers on Radio's Contribution to Engineering, Strength of Materials, A Proposed National Institute, and the Field of Section M (Engineering)

AT THE Annual Meeting of the American Association for the Advancement of Science, held in Nashville, Tenn., during the closing week of 1927, Section M held a morning session at Vanderbilt University, an afternoon session, and a dinner held jointly with the Engineering Association of Nashville, and Section C (Chemistry) of the association at which an address was given.

The morning program included papers on subjects of general interest but also of local application. Wilbur A. Nelson, State Geologist of Virginia, discussed methods of developing the natural resources of the state; Major John F. Conklin, U. S. A., told of the power possibilities of the Cumberland Drainage area; C. N. Boss, Tennessee State Highway Commissioner, dealt with the development of a state highway system; and George F. Fischer, Smoke Inspector of Nashville, discussed smoke abatement in Nashville.

C. F. Fountain, of the George Peabody College for Teachers, representing the Institute of Radio Engineers, spoke of Radio's Contribution to Engineering. By means of animated motion pictures he explained the action of the radio tube and other parts of the receiving and sending apparatus from the standpoint of the electric theory. Radio's stimulation to youth of today to enter the study of engineering science, he said, was perhaps its greatest contribution.

The afternoon session was opened by the address of the retiring Vice-President, C. R. Richards, of Lehigh University, on the Functions of Section M. From early times, he said, men endowed with powers of observation, deduction, and ingenuity became the master craftsmen, and these were the progenitors of the engineer. Early methods of guessing the solution of a problem had been replaced by analytical methods.

As a class, engineers, the speaker continued, were now more concerned with the adaptation of existing knowledge to their needs than with the extension of knowledge. Occasionally their needs were such that they were, perforce, led to explore somewhat the boundaries between the known and the unknown, but they were generally content if this process developed empirical relations that satisfied for the moment their peculiar requirements or if some difficulty in design or operation was temporarily met. While for a time empirical methods might be sufficient, sooner or later every engineer and every industry would recognize the necessity for precise knowledge of processes and materials and for exact methods of analysis that could only be supplied through the aid of the fundamental sciences.

Until recently men responsible for the design and construction of structures and for the control of industry had been trained as apprentices and their effectiveness had depended upon their natural adaptability for such work and their practical experience. The development of scientific and technical education had, however, greatly modified the training of such men and it had increased their efficiency. The advancement of science had been so rapid during recent years that now even the best product of a technical school was only moderatly well equipped to avail himself of the latest achievements of physicists, chemists, and other specialists in the fundamental sciences. More and more the engineer must work in close cooperation with those concerned with these sciences, and, for certain classes of work, his own training would need to be greatly modified and expanded.

In addition to the principal engineering societies there were nearly 600 others, so that this field was well covered. Section M, Dr. Richards said, had no place as an additional society. Its place was to bridge the gap between engineers concerned with the application of existing knowledge and the fundamental scientist concerned with the adornment of learning through fundamental research. Engineers should use Section M to voice scientific needs and achievement in adapting science to industry, and the scientist could forecast important applications of new theories and important discoveries. Publication of this information was also necessary and should be provided for by the association. The great purpose of the section was to establish a bond of sympathy between scientists and engineers.

N. H. Heck, Coast and Geodetic Survey, Washington, D. C., discussed the Earthquake Situation in the Mississippi Valley. Calamities coming at long intervals, he said, were specially hard to deal with since their arrival was not anticipated and the community did not learn how to deal with them. Mid-continental earthquakes were relatively few and theories to account for them had been advanced, one of them being change of load on the earth's crust through erosion and sedimentation. The great New Madrid earthquakes of 1811–12 were described, as well as their effect in causing great topographic changes over 30,000 square miles. A plan was outlined, which was patterned on the investigation now going on in California. This included operation of seismograph stations in the New Madrid region, precise triangulation, and leveling, the former through local initiative and the latter by the Government.

J. A. L. Waddell presented at length his remarkable conception of a proposed American National Institute based on the Institute de France, but greatly enlarged. The object and plans were described in great detail, going far beyond the field of engineering. The suggestion was made that Section M might initiate this great undertaking. Considerable discussion followed, and it was decided that owing to the great scope of the undertaking and the comparatively small number of members of the section present, the plan should be referred to the Section Committee with instructions to report at the New York Meeting and in the meantime to secure publication in whole or in part as may be practicable.

H. F. Moore, of University of Illinois, gave the dinner address on "The Mechanics of Materials, A Contribution of Applied Science to Pure Science," extended extracts from which will be found on page 118. Not a few of the fundamental concepts of pure science, he said, had been developed by workers in applied science. Mechanics of materials was a striking example. The ancient Greek had held the scholar as above mean and manual labor, and while this had developed the art of architecture to a high degree, it had contributed little to the science of structural design. Galileo, in founding the science of mechanics of materials, had drawn his inspiration from the Venetian shipyards, and Hooke's law had been discovered while he was working on an invention. The theory of mechanical failure of solids and determination of the limits of reliability of the theory of elasticity, Professor Moore said, were products of the engineering laboratory. In the future, development of mechanics of wave stress would probably be demanded. Intellectual aloofness from practical application and self-satisfied contempt of theory were alike evidence of a narrow mind. The highway between pure science and applied science was not a one-way street.

Book Reviews and Library Notes

THE Library is a cooperative activity of the A.S.C.E., the A.I.M.E., the A.S.M.E. and the A.I.E.E. It is administered by the United Engineering Society as a public reference library of engineering and the allied sciences. It contains 150,000 volumes and pamphlets and receives currently most of the important periodicals in its field. It is housed in the Engineering Societies Building, 29 West 39th St., New York, N. Y. In order to place its resources at the disposal of those unable to visit it in person, the Library is prepared to furnish lists of references on engineering subjects, copies of translations of articles, and similar assistance. Charges sufficient to cover the cost of this work are made.

The Library maintains a collection of modern technical books which may be rented by members residing in North America. A rental of five cents a day, plus transportation, is charged. In asking for information, letters should be made as definite as possible, so that the investigator may understand clearly what is desired.

Emile Berliner

EMILE BERLINER. By Frederic William Wile. The Bobbs-Merrill Co., Indianapolis, Ind. Cloth, 6 × 9 in., 353 pp., 30 illus., $4.

REVIEWED BY WILLIAM BRAID WHITE[1]

IN HIS unpretentious but intensely interesting "Life" of Emile Berliner, Frederic William Wile has performed a service to the historians of modern civilization. For it would not be too much to say that the inventor of the microphone, by virtue of his invention, has exerted an influence upon the manners and customs of today not surpassed by any man now living, and this despite the fact that he has never been prominently in the public eye.

Mr. Wile has done his task well and has made a story surprisingly interesting, even at times enthralling, as in that part of the book which deals with the first meeting of the young German inventor and Gardiner Hubbard of the infant Bell Telephone Company, a meeting which was to have such extraordinarily fruitful results. He has told his story simply and calmly, allowing the facts to speak for themselves, as in the case of Emile Berliner they may well, in more senses than one, be said to do.

Born in Hanover in 1851, Emile Berliner came to the United States in 1870. He had shown interest in scientific matters in his native land and this interest was redoubled after he had settled down to American life. He did not at first have an opportunity of seeing Bell's magnetic undulating-current receiver and transmitter, which was shown at the Centennial Exposition of 1876. His own crude experiments were attempts to work through battery current using a diaphragm, a spring, and a screw. A visit to the central fire-alarm station at Washington, where he was living during the winter of 1876–7, gave the hint to his active mind of the principle of variable pressure, namely, that changes in pressure of one contact upon another would bring corresponding changes in the intensity of an electric current passing through. Hastening home he rigged up a diaphragm with a steel-button contact and a galvanometer. Pressing the diaphragm ever so gently he saw the needle of the galvanometer deflected. He had hit upon the principle of the microphone: loose contact and variable pressure. Thus was brought into being the one invention which Bell's telephone needed to make it commercially practical. The whole revolutionary device sprang from the inventor's brain when the chance observation of a telegraph operator pressed the hidden metal spring. Thus wonderfully and mysteriously does the realm of mind operate.

The long story of Berliner's meeting with the Bell Telephone Company's officials, of the early disheartening struggles through which Bell and his associates had been going, of the first patents, of the long interference proceedings terminating triumphantly in the complete vindication of Berliner's claims to priority, of the rapid and extraordinary growth of telephony, all these one must leave the biographer to tell. He has told the story as well as it can be told, and it is an extraordinarily fascinating story.

The next great phase of Berliner's career came of course in 1883 when he set up his new house in Washington and began the line of experiments which led him to the invention of the fundamental principles of the disk phonograph or "gramophone." Not merely did he go far beyond the original device of Thomas Edison, but by conceiving the idea of recording upon wax in such a manner as to permit the construction of a metal matrix from which records to any number could afterward be pressed, he laid the foundation of the great talking-machine industry of today.

One might go on much further, but the reader will do better to get this fascinating volume and read it for himself. Here he will learn how from the telephone to the gramophone and from the gramophone to radio the microphonic principle brought forth by Berliner has gone its beneficent way, until today it is safe to credit the inventor with having done fundamental work of an importance to present-day civilization which actually can hardly be surpassed. To try to conceive a world bereft of radiotelephony, of the talking machine, or even of the telephone itself, is to put too strong a strain upon today's powers of imagination.

Still hale and alert at seventy-six years of age, Berliner has more recently turned to philanthropic work, of which a description is painstakingly included by the biographer.

The story of the German immigrant boy who became one of the key-inventors of the modern age affords a wonderfully stimulating example to the youth of today.

[1] Consulting Acoustic Engineer, Chicago, Ill. Assoc. A.S.M.E.

Books Received in the Library

FESTIGKEITSLEHRE FÜR INGENIEURE. By H. Winkel. Julius Springer, Berlin, 1927. Bound, 6 × 9 in., 494 pp., diagrams, 26 r.m.

A general textbook on the strength of materials in which theoretical considerations have been treated in as clear and easily understandable fashion as possible, and their practical application illustrated by many examples.

Resistance to tension, compression, bending, torsion, etc. are first discussed. Statically indeterminate systems are then treated, followed by chapters on springs, pipes and hollow vessels, plates, and revolving wheels and pulleys.

GRAMMAR OF TEXTILE DESIGN. By H. Nisbet. Third edition. D. Van Nostrand Co., New York, 1927. Cloth, 6 × 9 in., 553 pp., illus., diagrams, 9 × 6 in., $9.

This treatise describes the characteristics of the principal types of fabrics and of their chief varieties and modifications,